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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTION OF BRITISH FOUNDRYMEN AND THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION.

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Aluminium in Cast Iron.

A quiet chat with most foundrymen will reveal that they have either tried or are regularly using aluminium for the purpose of rendering the metal more hot and fluid. Aluminium is regularly used in steel manufacture. It is known in at least one district as the "bad-melter's friend," because a real "lively" cast can be more or less efficiently "killed" by its use. At one time it was regarded as a "cure-all" in the manufacture of steel, but later, owing to extravagant additions by inefficient melters, it received a bad name. It was found that under the microscope non-metallic inclusions were found, existing no doubt in the form of alumina (Al_2O_3). There are three places in which aluminium can be added in steel manufacture—the furnace, the ladle, and the ingot. Obviously, it is in the last place where the aluminium has the greatest chance of being detrimental, and it therefore follows that the furnace is the best place. Great practical difficulties exist in getting the aluminium beneath the slag, and any reaction with the slag is a waste of time and money. However, by the preparation of suitable contrivances, this difficulty can be overcome. It is thought by some investigators that aluminium in cast-iron precipitates the carbon as finely-divided graphite: others assert that it coarsens the grain.

However, the principal object in the foundry is to add from 0.02 to 0.05 per cent. by weight to the ladle for the purpose of heating up the metal and render it more fluid. The heat-giving reactions of aluminium are commercially exemplified by the well-known alumino-thermic processes, which are used for the manufacture of alloys and for welding. If the truth could only be established, it would be found that a very large percentage of iron-foundrymen are regularly using aluminium, but do not care to mention the fact. At a recent meeting of foundrymen, practically everyone present either was regularly using or had used aluminium. It would be preferable for them to say definitely the results they had obtained or were obtaining, as their metallurgical confrères could help them, because aluminium is a very sensitive element, and cast iron varies so largely between a sash-weight to an automobile cylinder. For instance, as far as can be visualised at the moment, 0.03 per cent. is beneficial, 0.25 per cent. detrimental, because of the non-metallic inclusions. By the time 3 per cent. is reached, according to Smalley, when added to hematite, a white, hard constituent was present, distributed in dendritic form. The same investigator has added 6 per cent., and noted its non-scaling properties. Latest advices, however, indicate that at 15 per cent. aluminium an alloy is produced which excells as a non-corrodible alloy at elevated temperatures. The value of aluminium is well known as a protective coating, especially when treated according to the calorising process. It is thought by some that a skin of alumina is formed, which is highly refractory. It appears, superficially, that cast iron alloyed with high percentages of aluminium either throws out to the surface a skin of alumina or, on heating, the aluminium constituent burns to Al_2O_3, and so forms a protective coating. The Schoop process of blowing aluminium on to the surface of cast iron acts similarly. Should wearing action be present, however, it is the new alloy which appeals to us, as each new surface exposed will automatically carry its quota of aluminium.

In steel practice, it is quite common for the shop manager to carry in his pocket a quantity of aluminium cubes cut to the size of a marble. From this source, he adds, when thought necessary, a minimum quantity. Sometimes just one ingot does not settle owing to some local dampness or dirt, and this purely local trouble is corrected by means of a relatively minute quantity of aluminium. At least one iron foundry manager has found a similar practice very beneficial, and states that blow-holes beneath runners and risers due to a mould being too damp, are eliminated through its use.

We hope that this subject will be discussed in the near future in both its phases that is, as a heat and fluidity provider and as a definite alloy for the production of non-scaling heat-resisting castings. If tackled in a sensible, technical manner in the immediate future, aluminium should never receive a similar appellation in the iron foundry to that bestowed upon it in the steel works.

The Value and Relation of Test-Bars to Castings.

By S. G. Smith, M.I. Brit. F.

The writer has for forty years experimented with and tested bars of various sizes and composition for many kinds of castings, and sometimes to such an extent that fifty bars per week had to be proved, hence many thousands of such have passed through his hands.

Test-bars are often more or less unsatisfactory, and they are often a bone of contention sometimes between the foundry manager and the engineer.

Unfortunately, up to the present time there does not exist a universal standard test-bar, and quite often there is no relation between the test-bar and the casting it represents. The reason why a standard universal test-bar regulated to withstand certain definite tests according to the strength or quality of iron required has not been adopted is difficult to understand.

The writer has been asked to make test-bars to represent many kinds of castings, and thought the limit was reached when transverse test-bars 2 in. by 1 in. by 42 in. long, of specified analysis for a 25-ton anvil block, was required. Also for certain castings a test-bar of similar size was called for which would give a deflection of $\frac{1}{4}$ in. at a load of 25 cwt. and $\frac{3}{8}$ in. deflection on a load of 30 cwt. The test-bar was not to break until the load was over 30 cwt.

This demand was quite new to the writer, and before accepting this work he personally supervised a number of tests to ascertain how the results met the demands.

These are shown in diagram form in Table No. 1, together with the approximate analysis of the mixture.

In ordinary practice the deflection is not taken until the bar fractures. The plan adopted in these special tests was to apply the load slowly up to 25 cwts., then record the deflection; afterwards

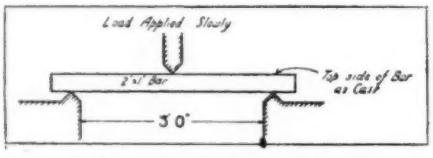

Table I.—*Showing the Result of Deflection Tests on C.I. Test Bars under Progressive Loads.*

Grade of iron.	Deflection inches.											
	A	A	B	B	B	B	B	B	C	C	D	D
Load, 25 cwts. ..	0.25	0.23	0.23	0.25	0.28	—	—	—	0.26	0.25	0.295	0.297
,, 26 ,, ..	0.26	0.24	—	—	0.285	—	—	—	—	—	—	—
,, 27 ,, ..	0.265	0.25	0.25	0.30	0.29	—	—	—	0.31	0.295	0.33	0.33
,, 28 ,, ..	0.28	0.26	—	—	0.30	0.31	0.296	0.30	0.32	—	—	—
,, 29 ,, ..	0.29	0.28	0.30	—	0.32	0.325	0.31	0.31	0.33	0.31	0.36	0.36
,, 29½ ,, ..	0.30	0.29	—	0.33	0.325	0.335	0.32	0.32	—	—	*	—
,, 30 ,, ..	0.31	0.30	—	—	0.33	0.34	0.33	0.33	0.34	—	—	0.37
,, 30½ ,, ..	0.325	0.30	—	—	0.34	0.35	0.335	0.34	—	—	—	—
,, 31 ,, ..	0.34	0.31	0.33	0.34	0.35	0.36	0.34	0.35	0.36	0.34	—	0.40
,, 31½ ,, ..	*	*	—	—	0.36	0.37	0.35	0.36	—	—	—	*
,, 32 ,, ..	—	—	—	—	0.365	0.38	0.36	0.365	0.38	—	—	—
,, 32½ ,, ..	—	—	—	—	0.37	0.39	0.365	0.375	—	—	—	—
,, 33 ,, ..	—	—	0.34	—	0.38	0.40	0.375	0.38	0.42	0.37	—	—
,, 33½ ,, ..	—	—	—	—	0.39	0.405	0.38	0.39	—	—	—	—
,, 34 ,, ..	—	—	0.36	0.40	0.40	0.41	0.39	0.395	0.44	—	—	—
,, 34½ ,, ..	—	—	*	*	0.41	0.42	0.40	0.40	*	—	—	—
,, 35 ,, ..	—	—	—	—	0.415	0.43	0.41	0.41	—	0.42	—	—
,, 35½ ,, ..	—	—	—	—	0.42	0.44	*	0.42	—	*	—	—
,, 36 ,, ..	—	—	—	—	0.43	0.445	—	0.435	—	—	—	—
,, 36½ ,, ..	—	—	—	—	*	0.45	—	*	—	—	—	—
,, 37 ,, ..	—	—	—	—	—	0.45	—	—	—	—	—	—
,, 37½ ,, ..	—	—	—	—	—	*	—	—	—	—	—	—

* Shows where failure of bar took place.

Analysis.

	G.C.	C.C.	Si.	P.	Mn.	S.		G.C.	C.C.	Si.	P.	Mn.	S.
A	2.232	1.000	1.683	1.000	0.872	0.050	C	2.707	0.663	1.997	0.913	0.625	0.066
B	2.342	0.788	1.324	0.572	0.413	0.059	D	2.952	0.558	2.424	1.150	0.645	0.053

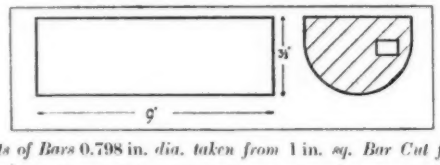

Table II.—*Showing Tensile Tests of Bars* 0.798 in. *dia. taken from* 1 in. *sq. Bar Cut from Pig-iron as shown in Sketch.*

Brand grade.	Tons per sq. in.	C.C.	Si.	Mn.	S.	P.	G.C.
Cold blast (Staffs.)	16.06	0.77	0.50	0.73	0.16	0.47	2.70
Special cylinder (Sheffield) ..	12.03	0.65	1.49	0.34	0.08	0.36	2.38
Refined iron (Cleveland, Yorks.) ..	11.5	0.76	0.95	0.48	0.045	0.07	2.59
Special cylinder (North Staffs.) ..	10.2	0.66	1.98	0.97	0.16	1,34	2,20
Derbyshire special	7.85	0.77	1.85	0.47	0.07	0.22	2.69
Hematite No. 3	7.90	0.40	1.87	0.72	0.12	0.03	3.80
Scotch No. 3	7.05	0.36	3.07	1.48	0.019	1.14	3.06
North Derby, No. 3a	6.74	0.25	2.50	0.65	0.04	1.50	3.00
North Derby, No. 3b	6.42	0.25	2.50	0.65	0.04	1.50	3.00
South Derby, No. 3	6.25	0.25	2.50	0.25	0.04	1,50	3.00
Mid Staffs., No. 4	9.7	0.61	1.68	1.25	0.082	1.17	3.00
South Yorkshire, No. 3	5.3	0.207	3.058	0.69	0.054	0.99	3.55

slowly increase the load by 56 or 112 lbs., and again record the deflection. This process was repeated until the bar broke. The method was rather tedious, and considerable time was spent in taking records. To those who attach importance to test-bars and mixings, a study of the table will be interesting. This is the only series of tests of this kind, so far as the writer is aware, that have been carried out.

Admiralty Specifications.

For liners, pistons and the like the Admiralty require a 1-in. square test-bar to withstand a stress of 2,500 lbs., and a tensile break of 12 tons per sq. in. Formerly the stress required on the tensile bar was 10 tons; why it is now 12 tons is not clear.

During the war the writer was unfortunate in having several pistons and liners rejected, due to the test-bar breaking slightly under the specification requirements. The test-bars were attached to the pistons; it was due solely to that reason that the bars broke slightly under what was required. If the bars were cast separate with the same metal they would have more than met the required test.

Now a medium-size piston, that is, one weighing about 5 or 6 cwt., varies in thickness of section from ½ in. to 2 in. This fact is mentioned now for the purpose of asking what size test-bar should represent this casting.

In the case just cited the Admiralty Inspector and Engineer were appealed to, the reply being they had no alternative but to reject the castings. Incidents such as this confronts the foundryman with the question, Which is the more important, the casting or the test-bar? In other words, are we producing suitable castings or test-bars? It is almost impossible sometimes to produce both at the same time. The inference to be drawn from these remarks should be apparent.

More Specifications.

The author has before him specifications to which he has had to comply which are demanded by the engineers of a large manufacturing firm of oil, gas and steam engines. These specifications relate to chemical composition and physical tests for various castings.

Now to conform to such and to obtain uniformly satisfactory results it is necessary thoroughly to know various brands of iron both physically and chemically. This statement is made in the broadest possible sense. Hence the writer not only obtained the chemical composition of the raw pig, but also applied a tensile physical test to each brand or grade of pig.

The physical tests shown in Table II. upon raw pig-iron are probably unique, and the following method was employed:—A short piece of pig about 9 in. long was broken off some twelve brands of pig-iron as usually supplied. A piece 1 in. square and 9 in. long was machined out of each piece from the position shown in the sketch, which was thought representative of the pig. This was tested in the usual way for tensile.

The name brands of the pig-iron, for obvious reasons, are not given, and are referred to as grades.

These results are shown in Table No. II., which will be very interesting when comparing tensile strength of raw material with analysis, fracture and number of grade.

Test-Pieces for Fuse Bodies.

One of the anomalies of cast iron specifications is apparent in the following:—The requirements for the above was a test piece taken from the centre of a casting 0.798 in. dia. by 0.798 in. long, and was required to give a compression test of 35 tons, with a contraction of not less than 7 per cent. This is a most peculiar test, inasmuch as the iron was expected to be hard and soft at the same time, which is not easy to obtain. The iron was required to be very dense, but not hard. The tests shown in Table III. were carried out in order to obtain some results of hardness, tensile and transverse stresses in comparison and relation to combined and graphitic carbon content. For hardness Shores testing machine was used; the tensile and transverse tests were carried out in the usual manner. Table No. III. are the results above referred to:—

TABLE III.—*Showing Physical Tests in Relation to Combined and Graphite Carbon.*

Test bar.	Shore hardness number.	Tensile tons per sq. in.	Transverse lbs. per sq. in.	C.C. per cent.	G.C. per cent.
No. 1	43	14.7	3,500	0.64	2.33
,, 2	42	14.9	3,680	0.71	2.28
,, 3	42	11.6	3,250	0.53	2.38
,, 4	41	14.4	3,200	0.66	2.07
,, 5	40	13.1	3,200	0.65	2.38
,, 6	40	14.7	3,800	0.77	2.07
,, 7	40	12.7	3,550	0.66	3.59
,, 8	40	13.1	3,200	0.65	2.38
,, 9	43	14.7	3,500	0.64	2.33
,, 10	40	14.9	3,680	0.71	2.28
,, 11	41	14.4	3,200	0.66	2.07
,, 12	42	11.6	3,250	0.53	2.38
,, 13	40	14.7	3,800	0.77	2.07
,, 14	40	12.7	3,550	0.66	2.59

NOTE.—A white iron gave hardness numbers of 74 and 77.

It was found practically impossible to comply with these requirements only under certain conditions. The castings were made in sand moulds, eight in box, or snap-flasks, from a mixture of iron giving a very dense and fairly hard iron, and if put under the compression test without further treatment would register 50 tons or over, with practically no reduction of area. This difficulty was overcome by annealing the castings for 24 hours at a temperature of 850 deg. C., which included heating up and cooling, i.e., 8 hours heating to 850 deg. C., 8 hours maintained at that temperature, and 8 hours to cool off.

It may be urged why not use a softer grade of iron and eliminate the annealing? But that would not produce the density required. To obtain this density some makers used permanent moulds—a much slower and more expensive method than producing these eight castings in a snap flask. The above heat treatment is one of the few ways in obtaining with cast iron great density with reasonable softness. This also allows for rapid and easy machining, and as these castings were made in hundreds of thousands, the machining of each, which involved twelve operations, was a most important matter.

Table IV. is worth considering, as the results show a great tendency to weakness brought about by the process of annealing.

TABLE IV.—*Showing Comparison of Tests and Analysis of Cast Iron Annealed and Unannealed.*

Deflection in inches.	Transverse lbs per sq. in.	Dia. of bar in inches.	Tensile tons per sq. in.	Size of bar.	Compression in lbs.	Contraction of area. %
*0.012	2,180	0.801	7.76	0.798×0.800	39,279	21.2
0.012	2,610	0.8015	11.4	0.798×0.806	51,650	12.0
*0.012	1,920	0.800	8.12	0.798×0.802	38,660	19.1
0.018	2,460	0.825	9.35	0.798×0.801	51,420	12.0
*0.014	2,150	0.801	7.00	0.798×0.800	38,660	22.1
0.014	2,500	0.821	9.20	0.798×0.800	52,210	13.8

ANALYSIS.

G.C.	Si.	Mn.	S.	P.	T.C.
*0.06	2.60	0.63	0.10	1.26	3.30
0.35	2.71	0.60	0.11	1.20	3.08

* Denotes annealed.

Standard Test-Bars.

For several months past much experimenting has been carried on with test-bars, and much time has been spent by the Institution of British Foundrymen's Branch committees and the central committee in discussing a universal test-bar, or bars, to be submitted to the B.E.S.A. for adoption. This body has been confronted with several questions, such as, Can a test-bar represent a casting?

After a long and varied experience, the writer is of the opinion that a test-bar does not, under any circumstances, represent a casting. A test-bar more often misrepresents a casting. It is not wished to imply that there should be no test-bars, but it is put forward that in many cases the foundry thinks it ought not to be necessary to supply test-bars.

Examples.

As examples, cylinders, liners, turbines and turbine steam chests are instanced, because the function of these castings is such that they require

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a dense and strong iron, which is proved in the pressure test. If there exists any defects in these castings, including weakness, porosity, etc., the pressure test will reveal them, and not the test-bar. Of course, test-bars and test-pieces should be made daily, and for all important castings. There is not sufficient of this important research work carried out. Analysis, fracture examination and the like should be daily routine work in the foundry, but this for their own information and guidance, and not to supply the results to the engineer.

If foundries must continue to supply test-bars such must be made under the most favourable conditions. This is not always obtained when the test-bar is attached to the casting. In other words, the test-bar must be given a fair chance. As to the suggested three different sizes of test-bars for physical tests, the author is whole-heartedly opposed to such, as it will prove to be most confusing, and a very contentious matter between engineers, inspectors and foundrymen.

The author's personal position in this matter is that one size bar should be adopted, and various loads and stresses applied, which would give some indication of the strength of the iron. This can be applied to transverse, tensile, compression and hardness tests.

As a member of a Branch Committee now considering a standard test-bar, the author has given this matter much serious thought, and he hopes the time is not far distant when foundrymen will be honest to themselves and the engineers and openly say that a test-bar does not necessarily represent the suitability of a casting.

It is time any distrust that may exist between the engineer and foundryman should disappear. It is vitally essential to all concerned that good faith should exist. The engineers do not want numerous tests for cast iron, and as the confidence between the two increases so will the demand in that direction cease.

Some Notes on Grey-Iron Castings.*

BY M. BENBOW, M.I.Brit.F.

The object in presenting a few notes is primarily for general information, and secondarily to afford an opportunity to bring up for discussion some of the many troubles encountered in the foundry.

The foundrymen during the past seven or eight years have had a very trying time, not only with labour troubles, but they have also had to put up with very indifferent grades of pig-iron, coke, coal-dust—in, fact, everything manufactured has been of an inferior nature. It is pleasing to note, however, that things generally are improving in quality, but, unfortunately, at a greatly increased price.

It has given the author much pleasure of late to read the various papers and discussions on castings without feeding heads, and he is pleased to state that he has been able to experiment on a small scale with bottom runner and dummy heads with fairly good results.

But he is very dubious as to what would happen in the case of heavy castings, which require to be machined all over to withstand a high pressure.

To give an example taken from the author's experiments, he had to make a number of U-bend pipes. The body of pipe was ⅝-in thick. It was tongued, and had grooved flanges 1¾ in. thick, tapering off to ⅝ in. over the bolt holes, which were cast in. The method used was to put a round riser on, between the bolt-holes, and to feed them with a rod. The result was a scrapped casting. The castings, by the way, were machine-moulded. The casting was made again, but this time without feeding, and also the riser was altered to assume a wedge-shape. This method gave satisfactory results, as all passed the test of 700 lbs. water pressure and 350 lbs. air test under water, so, in the author's opinion, it appears that feeding with rods in many cases is useless and a curse to the foundryman. Apparently there is much art in feeding castings with rods. Many moulders cannot feed a job properly. The author imagines that foundrymen can go to two extremes—they can over or under rod-feed castings.

Pouring Cylindrical Castings.

An interesting query is, Should steam or compressor cylinders be run at the top or the bottom of the casting? The author has experimented with both ways, with various results, but he is inclined to lean towards bottom running. He has not had an opportunity of trying the Ronceray method of running with small pencil-like runners on top of castings, and would welcome any local information as to its practical worth. Another point of interest is the question of heads for cylinders. What is the best shape of head and the best depth? Is it necessary to put on heads at all? The author does not put heads on small cylinders, but on the larger sizes and ammonia compressors it is his practice to put on heads from 8 to 10 in. deep, and from 4 to 4½ in. at the top of the head, which taper off to 2½ to 3 in. on the casting. This method is generally very successful, but the author cannot say at the moment that it is wise to make this a definite rule.

Casting Temperatures.

Many foundrymen have different views as to what is the best temperature at which metal should be poured into cylinders for high-pressure work. The author's practice is to melt at a high-temperature, but to give the metal a little time before pouring, which gives the metal an opportunity to cleanse itself in the ladle. This, too, opens up an interesting point for discussion.

Surface Defects.

Another great trouble to foundrymen is hollow scabs or buckles on castings. In his personal experience the author has seldom seen hollow scabs on green-sand castings. If they do occur, it is generally through the mould being crushed at some point. In dry-sand work sometimes these scales do appear, even if the mould is thoroughly dry. It is sometimes thought that the cause of this trouble is through steam being "pocketed" in the vents, especially when the castings are made in the floor, on a coke bed, which has been used several times without being changed. The heat of the drying stoves or fires causes this steam or dampness to come up and gather in the vents. To obviate this, it has been found to be good practice to leave the vent holes open, not only off the coke bed, but also round the job itself on the joint of the mould. Not only does this allow the steam or dampness to escape, but is a certain help in drying.

Cupola Troubles.

A good many of the foundryman's troubles start with the cupola through various causes. Some, no doubt, are due to mismanagement, inferior coke and ganister, and atmospheric conditions. The last-named the author has found to have a good deal of influence on the melting of metal. It has been noticed that on some days, after lighting up, the cupola would not pick up any heat until the blower was put on; consequently, the metal has been very sluggish, sometimes causing the tapping hole to freeze up, and unless there is to be a heavy blow, upsetting everything generally for the day.

Cores Oils and Sands.

After many trials of the various oils on the market the author has found that they are all much of a kind. At present he is using spermoline. But, after all, linseed oil is about one of the best so far found. But the author is quite convinced—in spite of what the manufacturers of core oils say—that the freer the mould gets the gases away the better the results obtained. Again, the manufacturers claim that there is no need to use core irons. It is admitted that it is not necessary to use so many as with the ordinary core sands. This recalls to the author's mind an Institutional visit to a foundry, where a lot of oil sand was used. One of the members picked up a core and casually asked if there were any core irons in it. The answer was "No." Now, whether by accident or design, the core fell to the floor, and there were irons in it. In reference to sands, the author has found that for ordinary small work silver sand is the best, especially for what is termed the "sausage" machine. The coarser-grained sand has a decided wearing effect on the dies and machine generally. For heavy work the Leighton Buzzard No. 2a silica sand is preferred.

* Paper presented to the London Branch of the Institution of British Foundrymen. Mr. Wesley Lambert in the Chair.

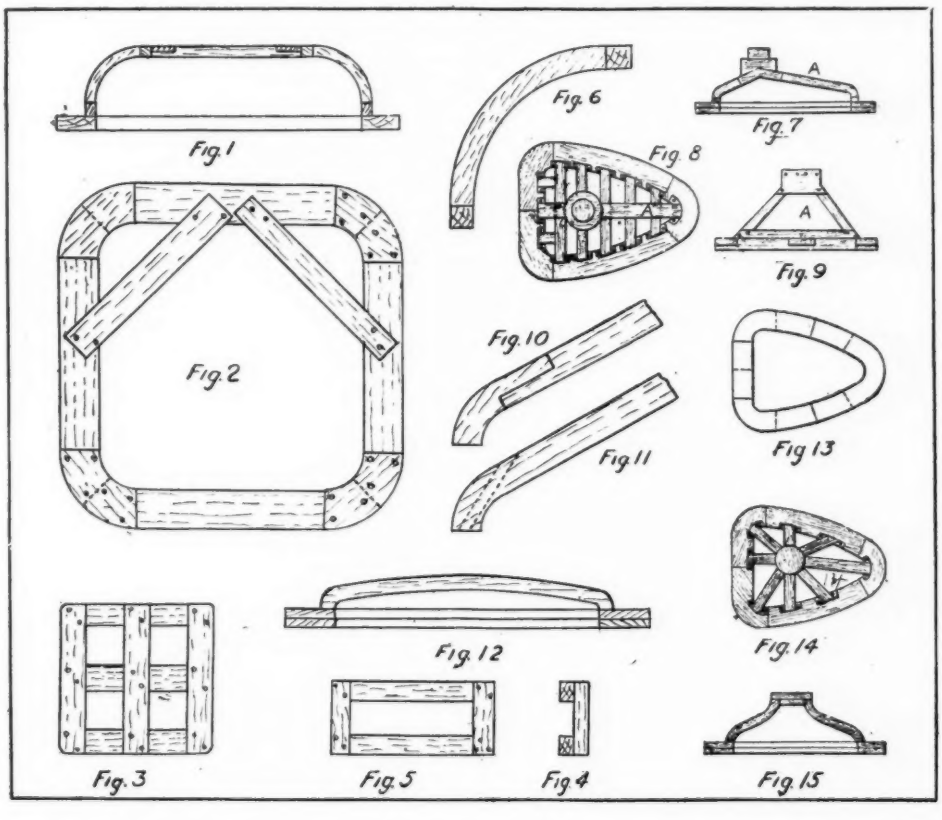
An Apprenticeship Course in Foundry Practice.—XXXVI.

By Ben Shaw and James Edgar.

SKELETON PATTERNMAKING.
Part 3.

In making skeleton pipe patterns the method of procedure is fairly well defined. It is always advisable to make the patterns in halves, but if this is not done the flanges at least are made in halves. The work always consists of a centre plate or plates to which the section or skeleton pieces are fastened. But with skeleton-patterns other than pipes the construction depends upon the design. With cylinder or condenser covers, for instance, it may be advisable to make a shell pattern in preference to a solid skeleton pattern. section pieces that would entail considerable labour carving from the solid.

When a patternmaker has set out a job that is going to be made by the skeleton method therefor, he has next to decide on the construction. It may be necessary, in addition to a base plate—which may be in the centre of the pattern—to make several frames. In some cases it may be advantageous to set down the main section pieces on the drawing board. Indeed, in some cases, where every piece has to be of different shape, it is almost necessary to do so. At corners, where the shape is so awkward that it is practically impossible to define it with section pieces, solid blocks



In other cases a half lapped frame may be more satisfactory than an edge-to-edge jointed plate. Then for a pattern of very irregular design it may be almost puzzling to decide how to make the basic part, the part on which the remainder of the pattern is built. However frail the section pieces of a skeleton pattern may be, the plate or plates on which they are built should be very strongly made.

Building on Base Plate.

In some pattern shops a very common job that is usually made by the skeleton method is that part of the steam port of a slide valve cylinder which breaks through the crown. It is convenient both for constructing it in the pattern shop and dissembling the cylinder in the foundry that, instead of the section pieces being laid separately on the top of the cylinder, they should be built on a plate. The outline of the plate is obtained from a plan of the cylinder set out on the shop drawing board. We do not show a sketch of the job, because it is mentioned simply to explain why it is frequently necessary to build skeleton parts quite separately from the main body, and screw them on afterwards. Flat shapes of irregular outline can often be made quickly by a base plate and should be used. This applies also to pipe work, of course. It is neither advisable nor fair to leave to the moulder the work of defining a shape.

Turbine Casings.

In many pattern shops large turbine casings are made skeletons. Such patterns appear to the novice distinctly complicated, but there is nothing particularly difficult about them. A turbine skeleton pattern is really just a number of separate skeleton constructions joined together, and if the apprentice gets a good knowledge of the principles even a turbine casing should not trouble him or be beyond his capacity, although it is not probable that his skill will be tested during the time of his apprenticeship.

In some pattern shops skeleton patterns are constructed just anyhow. There is no attempt at method as long as the work is to the design and will mould. Thus even when a large pattern is being made, after the base plate and either temporary or permanent frames that are necessary are set up, parts are nailed or screwed without thought as to dissembling after moulding. Such patterns are usually screwed up in the foundry, and when the patternmaker goes he wastes con-

siderable time sorting out the various parts. In all probability some of them are broken. This is the crudest kind of skeleton patternmaking, and if the first cost is low, the final cost is not. As far as possible skeleton patterns should be built of sections, each section comprising, it may be, a dozen or more pieces.

Irregular Shapes.

When making some patterns it is extremely difficult to mark off the shape from the drawing. In nearly all cases it could be done, but it would involve the setting out of innumerable views on the drawing board. A really skilled patternmaker, apart from the question of time, takes a pride in constructing work from as few views as possible. Furthermore, when, say, a square section changes in its entire length to a circular section the drawing of various shapes to represent those at definite intervals in the length takes considerable time. It frequently happens also that the development of a shape may not appear satisfactory when transferred to the work. It is, therefore, almost necessary with many patterns to fit rough blocks on plates or frames and shape them when in position. The outside may be shaped first in the case of a shell skeleton pattern, and when a good shape has been obtained the thickness of the various parts can be gauged and the pieces cut to define the inside shape. This is, perhaps, the most difficult part of skeleton patternmaking, because so much depends upon the eye. It is not always possible to use templates or a straight-edge. In this connection it may be said that while the accurately drawn template is nearly always an advantage, its importance can very easily be overrated. With the skill that comes from experience, it is often possible for the patternmaker to execute work much quicker without than with a template, and the resultant casting be equally as satisfactory.

Skids.

Fig. 1 shows a section of a pattern for a casing door for an ordinary slide-valve cylinder. It is not usual to set down a plan on the drawing board, as it has to be set down for building purposes on a level floor or board. If there is not a special building floor or a board sufficiently large skids would be used. As in many patternshops there is no need for skids, it will be as well if we explain their purpose, as they form a very essential part of patternshop equipment where large work has to be constructed. Skids are battens 4 or 5 in. wide and 2 in. thick, and sufficiently long to serve as a bearance for the whole of the pattern. The timber used for skids should be very dry. These skids are screwed to the floor edgewise and their top edges planed level, parallel straight-edges being used to test them for being out of winding. They form what is equivalent to a level floor.

For some patterns it might be necessary to have a series of skids parallel to each other and about 18 in. apart; for others, however, two or three skids suffice, and they may be 5 or 6 ft. apart. In other cases, skids may have to be placed at right angles to each other. In some shops, where skids are in almost continuous use, a part of the floor is set apart for building, and the skids are never lifted. They should be tested for being level, however, before starting to build on them. Even when skids are laid down temporarily it is quite a common practice to reserve them for the purpose, because not only is timber saved, but old skids are well seasoned and less likely to warp or shrink.

Casing Door.

To return to the casing door, the first operation would be the jointing of the flange; Fig. 2 shows a common and quite satisfactory way of doing this. Four battens of yellow pine would be mitred, as indicated by the dotted lines, and half-laps cut from them so that mahogany or other hardwood, half the thickness of the flange, could be fitted. When these hardwood binding pieces have been screwed into their positions, the flange could be drawn off and dissembled for convenience in finishing it, care being taken to mark the various pieces to ensure their being replaced accurately. The two diagonal battens are to prevent the flange being knocked out of square. In addition to screwing the battens on to the flange, dowels should be inserted; although these battens would have to be removed while the flange is on the skids they would be replaced when the pattern was finished. An alternative way of making the flange would be to build it of two thicknesses of pine, a method that would be preferable if an elliptical flange was being built. A top frame would be the next part to be made, a view of which is shown in Fig. 3. It has to be an open frame to enable the moulder to ram inside the pattern, and the dimensions of it would be, in thickness, of course, the required thickness of the metal, as the pattern is to leave its own core; the length and breadth would be the distances between the centres of the circular corners. Two rough frame supports, shown in Figs. 4 and 5, would be made to support the top frame. They would be planed parallel to the height of the underside of the frame, from the bottom of the flange, but they would not need to be half-lapped. They could be fixed to the floor by means of buttons or pocket screws.

The top frame could now be set in position, by squaring the centre lines on it carefully with the centre lines on the floor. This could be done easily with a set-square or a plumb-bob. A few screws would hold the frame securely, while the shape is being built about it. The large radius can now be filled in. On the drawing board two lines would now be set down 1 in. from the top frame and 1 in. above the flange. Strips could now be cut out the length on the straight on each side, and also circle strips to complete the corners.

It would be advisable to make a template for the grounds, which on the straight might be made about 2 in. broad, 3 in. being left between each ground. On the circle corners 1 in. would be broad enough for the grounds to ensure getting a good shape. The grounds would be screwed to the strips as shown in Fig. 6, and then the whole length of grounds can be laid in place and screwed to the top frame and the flange through these strips. If a ground were screwed to each end of the strips first it would not be difficult to screw on the others. When all the grounds had been fastened on the job could be unscrewed from the floor and finished off on trestles.

Condenser Doors.

The ordinary condenser door is usually swept up, but a type of condenser that is frequently used nowadays is the heart-shaped "Uniflux" condenser. On the larger condensers they are usually shallow, as in Fig. 7; but in smaller condensers they are deeper, as indicated by the framework at Fig. 9. It has been found by experience, in most patternshops doing this class of work, that a skeleton pattern leaving its own core gives good results with the shallow design, but with deep doors the practice adopted is to make a skeleton pattern of a different kind, allowing the moulder to sand or clay thickness it. The practice, however, is not always adhered to, and a shell pattern is sometimes made for a deep door. For the sake of those readers who have not had much foundry experience this clay- or sand-thicknessing may be explained as the ramming of sand into a square box having a thickness similar to the required thickness of the metal or the rolling of clay to that thickness. Some moulders prefer clay, others sand. When the pattern has been drawn and the mould finished, the moulder introduces his sand or clay thickness, and thus gets a core-box. The chief objection to this method is the danger of the metal not being of uniform thickness.

We shall consider first the construction of the pattern shown in Fig. 7. As with the casing door, it is not necessary to set down a plan on the drawing-board, but a front elevation or section, and as many cross sections as are given on the drawing. The flange would be built of two courses of segments and well glued and screwed. If it were built with care 1-16 in. is all that would need to be left inside and outside for finishing off.

On top of this flange a segment the thickness of the metal and about 1 in. deep would be screwed. A piece for A, Figs. 7 and 8, would now be built in three or four courses, making up about 4 in. broad. The rest of the job would all be built against this rail. It could either be pocket-screwed to the segment on top of the flange or, better still, a short strip about 7 in. long could

be screwed to it, and this could be screwed down to the segment on top of the flange. The cross-section pieces could be made conveniently out of 3-in. timber. If rough templates were made for the various sections a saving in timber would result. The rough pieces could then be placed in position against the centre rail. Lines could be scribed above and below the centre rail on the end of the piece being fitted, and if these lines were carried parallel to the bottom flange till they meet lines drawn vertically from the flange, the inside and outside radii could be described and the piece cut at the band-saw and then finished at the bench.

The short grain in these section pieces is decidedly a weakness, and sometimes they are made, as shown at Fig. 10, of two pieces half-lapped; but the writers have found that by carefully inserting a ½-in. hardwood dowel, as shown in Fig. 11, a fairly strong job is made. These section pieces would be kept about 9 in. apart. Cross-pieces would be fitted about 6 or 9 in. apart between these main-section grounds, and they would be pocket-screwed to the main grounds. Care would have to be taken to have all the screws visible, as the moulder will unscrew the pattern. At each end several small grounds would be run from the flange to the first cross-ground. In work of this kind it is very difficult for the draughtsman to define the shape accurately; hence the pattern-maker must, to some extent, use his own judgment. The draughtsman may alter the shape when he sees the pattern. There are usually several manholes on these doors, and they are fitted solid, or with a built ring if they are very large or deep, and a print put on. A core-box, of course, has to be made. There are lifting lugs, small bosses, etc., on these doors, but they are simple and not worthy of consideration in this article.

The saucer-shaped door shown in Fig. 12 would be made in the same way as the one already described. Of course, while the method of construction is similar, small differences in design would test the initiative and resource of the patternmaker.

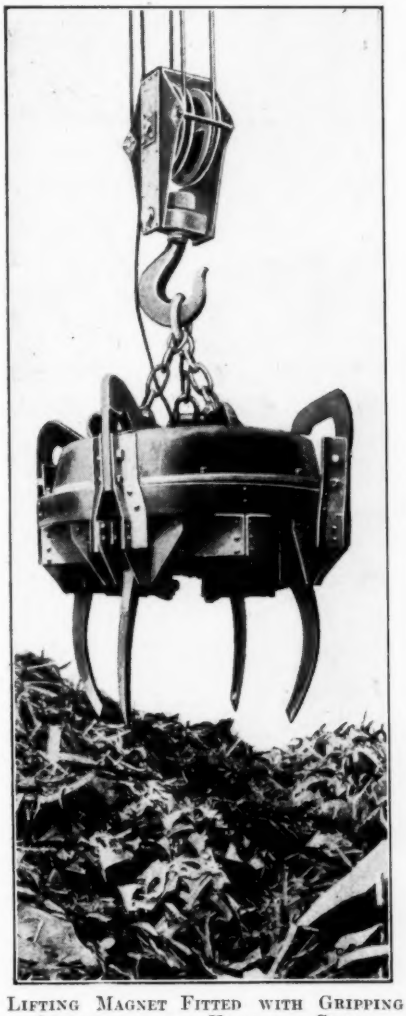
The construction of the deep door shown in Fig. 9 would be altogether different. A shell pattern could be made for this door, but it would be too flimsy. A half-lapped frame like A, Fig. 9, would first be made to the longitudinal section. This would be screwed to the flange, the construction of which is illustrated in Fig. 13, with square blocks. The section across the centre of the manhole A could now be made with side frame or one-thickness plate screwed to the actual frame. In order that the grounds, which should only be about 3 in. apart, may not be more than 3 or 4 in. broad, rough sloping pieces of pine or spruce can be run on the angle from the flange to the central frames both along the sides and across the broad end. The grounds could now be fitted on top of these pieces, and the shape of each ground will have to be drawn in place and the position marked so that it could be replaced without trouble when it is finished. It will be noticed that the manhole is made up between the frames with segment pieces before the grounds are fixed on. The construction of the doors shown in plan in Fig. 14 is similar to the above, except that the manhole is not on the centre line, consequently only a cross-frame is possible. In such a type it is sometimes necessary to have a check on the underneath side of the manhole door, and all the grounds are carried from the bottom flange to the top.

It is not always possible to make the grounds from one thickness timber. Fig. 15 shows a cross-section of a door for which it would be necessary, to avoid waste of timber, but more especially for strength, to build the grounds in two or three thicknesses. It would be necessary to build them much broader than the finished thickness, to allow of the shape being drawn when they are placed in position.

German Gun Steels.—The Research Department, Woolwich, have just published their R.D. Report No. 57, dealing with German gun steels, giving their chemical analysis, micro-structure, mechanical tests, cooling curves, etc. Copies may be obtained from the Stationery Office.

Scrap Lifting Magnet.

The carrying capacity of a lifting magnet depends on the shape and the nature of the material to be handled. With solid bodies, such as blocks and thick plates, it will be fully utilised. For example, an ordinary circular magnet of about 5 ft. dia. is capable of lifting a 5-in. plate weighing about 30 tons, but it will only attract about 0.7 to 0.85 ton of cast-iron scrap, while, with bulky steel turnings, the carrying power will sink even to a third of a ton. For any magnet it is difficult to pull out the entangled pieces of



LIFTING MAGNET FITTED WITH GRIPPING ATTACHMENT FOR HANDLING SCRAP.

a scrap pile, as the point of contact is too small to develop sufficient magnetic force. This drawback is claimed to have been overcome by a magnet of German design, which is provided with a gripping attachment (see figure), by means of which the scrap is grasped and mechanically, as well as magnetically, held.

Galvanising Malleable Iron.—An interesting Paper on malleable iron was recently presented to the American Institute of Mining and Metallurgical Engineers by W. R. Bean, head of the Research Department, Eastern Malleable Iron Company, Naugatuck, Conn., under the title "Deterioration of Malleable in the Hot-dip Galvanising Process." The investigation claims to show that the deterioration of malleable iron in the hot-dip galvanising process is intimately associated with the amount of phosphorus and silicon in the iron. When both the phosphorus and silicon are low, the malleable iron will withstand the process best with practically no deterioration. High-phosphorus and high-silicon irons are practically certain to be embrittled by galvanising, but if the phosphorus is about 0.10 per cent., the silicon may be as high as 1.20 per cent. without serious trouble.

Some Random Notes on Electric Steel Furnace Practice.*

By Vincent C. Faulkner, M.I.Brit.F., M.A.T.F. (Francais),
Editor of The Foundry Trade Journal.

Introduction.

For an Englishman to present a paper on electric furnace practice to a French audience requires some explanation, in view of the fact that many engineers regard the electric furnace as peculiarly a French baby. In speaking of the electric furnace the names of Héroult, Keller, Girod naturally come into one's mind. However, despite the fact that the French have originated so much in this domain, yet no fewer than thirty furnaces exist in France which have been either designed or built in Great Britain. This figure probably represents at least one quarter of the total number of electric furnaces in France.

Present State of Electric Steel Furnaces in England.

Practically speaking, only five types of electric furnaces are exploited to any extent in England—Héroult, Electro-Metals, Greaves-Etchell, Stobie, and, to a much lesser extent, the Snyder. In origin they are respectively French, Swedish, British and American.

British.

Those, however, which are not British have been modified, improved, and in every case have been built in England.

With the close of the war orders for new electric furnaces in England practically ceased, the demand usually being met by the purchase of second-hand material from works who over-purchased during the war. Notable exceptions, however, are (1) a triplex plant, near Sheffield, which utilises mixer metal, blowing it in a 10-ton converter, and finally refining in a Greaves-Etchell furnace of similar capacity; (2) a duplex system recently installed by Messrs. Edgar Allen & Company for the manufacture of steel castings. In this case Stobie furnaces are used. Melting is accomplished in a 10-ton furnace, which acts as a reservoir, 3-ton lots being transferred to a 3-ton furnace to be refined and finished. All triplex and duplex plants are either a great success or a dismal failure, arising from the fact that if one link in the chain breaks there are several sets of men idle. The Americans, however, usually manage to make such processes a commercial success.

American Progress since the War.

America, like England, suffered a severe industrial slump after the war, and practically no new plants were installed until 1922, when 28 were ordered. Amongst these was a furnace of 60 tons capacity of the Greaves-Etchell's type, known in France as the Schneider-Greaves-Etchell—at the River Rouge plant of the Ford Company. The body of the furnace is 5 metres by 6 metres 30.

The walls are two bricks thick, and the five doors, excluding the tapping spout, which also serves as such, are 93 cm. wide, eight 60 cm. dia. carbon electrodes bearing the current to the bath. There are four 3,000-k.v.a. transformers.

Underlying Principles.

If a furnace is required for the manufacture of steel castings the buyer should consider carefully the following factors :—

(1) *The Electric System.*—From the various sellers the buyer will hear, no doubt, that the disposition of the electric system involves various metallurgical phenomena. All these should be discountenanced except the number of electrodes the system involves, and whether bottom heating is incorporated.

(2) *Number of Electrodes.*—If a furnace can be worked satisfactorily with one electrode, even that is one more than the ideal, for with every extra electrode introduced the consumption per ton of steel produced is increased. Unfortunately, with the usual type of electric supply available, one-electrode furnaces are not practical unless a battery is installed.

Conducting Hearth Furnaces.

Four out of the five types of furnaces used in England have conducting hearths. The type used has been given in detail by Mons. Marcel Gillot in a paper read before an engineering society at St. Etienne.† As a matter of fact, that is the hearth which has been developed by the author and communicated to the French firms with which he has been temporarily associated. In the States and in a few works in England endless trouble has been attributed to conducting hearths, but the author has yet to learn of a single accident attributable to this feature occurring in France in the types of furnaces used in England. An outstanding metallurgical advantage of the conducting hearth furnaces is that should melting be stopped through failure of electric current, and the bath becomes frozen, it can be, without undue trouble, remelted and brought to normal condition. This is extremely difficult in the furnaces restricted to top heating only.

Rectangular or Circular Furnaces.

For a three-electrode furnace a circular furnace is the natural design, but for two it should obviously be rectangular. With four either shape is permissible.

Circular Furnaces.—Theoretically a circular furnace is preferable, but for the walls it involves the use of special shapes or a considerable amount of brick-cutting, which with magnesite bricks is a serious cost. For the roofs, again, bricks of special section are required, and any attempt to substitute ordinary squares results in the use of extra cementing material.

The preparation of the holes for the electrodes is fairly complicated, and any large movement from centres often involves considerable adjustment to avoid broken electrodes.

Rectangular Furnaces.

Being composed of straight walls and a plain arched roof, once the expansion of the type of brick used is known definite expansion allowances can be made. No cement is required or should be used. To take up the expansion of the roof, preferably paper should be inserted, and the construction is better if done in straight independent rows and not bonded. This has two advantages, the first being that repairs can be effected without having to bond new bricks with old ones, which is detrimental. The second is that no brick is under excessive pressure. If it is considered that the corners of the furnace are too far away from the source of heat, corner plates can be inserted, making an apparently rectangular furnace an octagonal one. Whilst this may not appeal to mechanical engineers, it is quite good metallurgical practice.

Though the quality of refractories is of great importance in electric furnace work, it is not intended to enter into the question here beyond pointing out that whilst some firms make their roofs last 120 heats others only reach 30. Obviously it is a question worth studying.

Tilting Mechanism.

The tilting mechanism of any furnace should be carefully studied before purchasing, and given constant attention afterwards. A favourite type of gear is that by which a revolving nut causes a screw to move to and fro, so making the furnace tilt forward or return. Unless such a system is carefully handled, the nut, owing to the abrasive action of the dust in the atmosphere in the shaft, will strip and cause the furnace to return violently to normal. This accident has occurred with more than one make of furnace, and has been known to smash the transformers. In this connection usually much consideration is

* A translation of a Paper presented to the Association Technique de Fonderie, in Paris, on March 16. Monsieur Ramas in the chair.

† See F.T.J.

given to the movement communicated to the tapping spout of the furnace. In the author's opinion, this is a question which can usually be overcome in a modern shop equipped with an up-to-date crane. The tilting gear mentioned will prove quite satisfactory if totally enclosed and otherwise well designed. However, a geared rolling furnace is preferable.

Electrode Carriage.

In some designs the electrode carriers are attached to the shop roof and hoisted clear of the furnace when teeming. This system the author condemns on four grounds. (1) High thermal losses at the time when every calorie is required to help to effect efficient repairs to the hearth, as there is nothing but the residual heat in the furnace to agglomerate the material used for this purpose.

(2) Owing to the exposure to the air the electrodes become reduced in size, which brings in its train numerous disadvantages and losses.

(3) The acid ash from amorphous carbon electrodes drops on to the roof, where often basic dust is present, and will, round the electrode holes, cause a very fusible slag to be formed, with the consequent rapid destruction of the roof. On the other hand, such a system usually allows the furnace to be tilted to a much greater extent than when the gear is attached to the furnace, and even deep pools of metal are drained, which allows of more effective fettling to be accomplished.

(4) No overhead crane can adequately serve the furnace.

There are three types of electrode carriages, all attached to the body of the furnace, which are commonly used. The first is a horizontal arm to which a vertical movement is communicated by a revolving screw and a nut sliding in a channel. This has superseded the rack and pinion system.

The second maintains the arms, which is carried by ropes and counterbalanced. Chain gearing is introduced into the rope system, which is actuated by hand or motor.

The third system incorporates the use of a bridge spanning the furnace body, and if four electrodes are to be used, two bridges crossing at right-angles are necessary. Over the electrodes holes two masts are built up from the bridge to form guides, and inserted in these are the electrode carriages, which are carried by ropes and actuated by hand or motors.

Now such a system involves, apart from the mechanical aspect, many metallurgical considerations. Primarily the roof frame cannot easily be detached, and roofs must be constructed *in situ*. For repairs, it requires that the furnace must be cooled sufficiently to enable a bricklayer to fix templates and battens for the reconstruction of the roof; such cooling may crack the side walls, and certainly involves a longer stoppage time for repairs than for any system which allows the electrodes to be taken completely out, the damaged roof removed and a spare one put on. However, it shows distinct advantage in other directions. For instance, the electrode water coolers and economisers can be suspended from the bridge so as to place a minimum weight of material on the roof.

The water cooling of electrode holders in a modern furnace is quite unnecessary. If a simple system of communicating movement in any direction to the electrode grips an undoubted advantage will be shown, as some makes of electrodes are not parallel and no amount of care in the adjusting of the holes in the roof can ensure that the electrodes will not grind on the sides of the holes. If any real pressure is set up, accidents in a variety of directions can take place, such as the displacement of bricks in the roof, the smashing of electrodes, and seizing of gearing and burning out of fuses or even motors.

Furnace Doors and Layout.

Generally speaking, both circular and rectangular furnaces are provided with three doors, including the tapping spout, but some small rectangular furnaces have only two, again including the spout. This depends on whether the furnace tilts in the plane of the two electrodes or at right-angles. The former economises shop space, allows of a stronger construction, having two full walls, whilst the latter allows of better facilities for repairs.

Essentially features of doors are (1) they should be sufficiently large to allow of the easy removal of a broken electrode and to take the largest size of scrap likely to be currently used; (2) they should take standard sizes of bricks; (3) they should not be so large as to "starve" the furnace unduly on opening; (4) they should be provided with a simple auxiliary mechanism so as to ensure that there is no current of air entering; (5) ease of changing is an added advantage.

Voltage and Power.

For normal steel-making purposes, three tappings, ranging from 60 to 100 volts, should suffice. Modern American practice has incorporated much higher voltages for quick output. This is to be strongly deprecated, as a survey of the most successful furnaces will convince the searcher that the best steel is being made in old-fashioned underpowered furnaces, where the melter has to take considerable precautions to obtain sufficient heat. If conditions give the melter no trouble in obtaining heat, then he is apt to teem at too high a temperature. Additional to this, with very high voltage, conditions are favourable for the fixation of nitrogen, which is possibly taken up by the steel with consequent poor results.

ECONOMISERS.

By this term is meant an apparatus which is superimposed on a water-cooled ring for the purpose of preventing a chimney effect. The more efficient the economisers, the less the attention that need be given to the doors. Each electric furnace house has its own design.

Stobie.

This originally consisted of a telescopic arrangement extending between the electrode grip and the water-cooler. It appears to be theoretically efficient but expensive. However, this has been discarded in favour of a plain cylinder surmounted by a tightly-fitting asbestos ring sandwiched in between two cast-iron discs. It rests on a deep water-cooler, and is supplemented by superimposed coils of asbestos rope.

Electro-Metals.

In this system three or more rows of segments are designed to slide and touch the electrode, the joints of each row being masked by the superimposed row.

Greaves Etchells.

The method adopted for the furnace, in Europe, is to attempt to cover the same ground as the Electro-Metals, but utilising only one row of segments. It has the advantage of being lighter. In the States, however, this furnace utilises a mechanism of cooling by varying the volume of the escaping gases until they reach below the combustion temperature. In considering the adoption of any type of economiser, the following factors must be taken into consideration:—

(1) Reduction in the working length of the electrode. If this is cut down too much it involves lowering the electrode during melting, and the improvements sought are neutralised.

(2) Excessive weight is detrimental because of the pressure on the roof, which decreases its life, through lowered melting-point and early renewals to withstand the applied pressure.

(3) Electrical losses through induction.

Amorphous or Graphite Electrodes.

The purchaser of a furnace has to decide at the outset his preference in most cases, for but few designers allow of the rapid interchange.

The author has no hesitation in expressing a preference for graphite on the following grounds:—(1) They are supplied with machine-cut joints; (2) they are of much less diameter than amorphous for the same electric current-carrying capacity; (3) they are essentially pure, which means that the buyer is purchasing what he pays for—*carbon* and not *ash*; (4) they can be relied upon to be parallel; (5) any small defect can be rectified by means of wood-cutting tools; and (6) they allow of stronger roof construction.

However, it is not so much on the direct but upon the indirect grounds which cause the weight of modern opinion to favour graphite, but before dealing with this aspect, in fairness, the one advantage of amorphous (apart from first cost), its one alleged advantage should be pointed out. Being of larger cross sectional area, amorphous electrodes mask the roof from the direct arc rays, which tend to destroy it. They do when freshly inserted, but as they very rapidly wear to a point quite as fine as graphite electrodes, such a claim cannot be substantiated.

Unless the quality of amorphous electrodes improve very materially, and very quickly, their position in respect to the electric melting of steel will be analogous to that now enjoyed by the induction furnace.

The disasters following in the wake of electrode troubles are:—(1) Effect upon personnel. This is important, for a real good melter may lose confidence in himself, and this confidence is the most important factor in the successful operation of an electric furnace. (2) The steel may contain too much carbon. (3) The removal of a broken electrode during melting involves loss of time and labour, and may damage the roof, jambs, water-coolers, economisers and electrode grips. (4) The insertion of a cold electrode into a hot bath may crack the roof. (5) Loss of heat units and the increase of electricity account. (6) Added difficulties in the construction of efficient economisers due to irregular shape.

Care of Electric Furnaces.

Any notes having reference to the care of electric furnaces must necessarily emphasise the necessity of carrying adequate stocks of materials and spare parts. The plant must undergo regular periodic inspection by both the mechanic and electrician. At the weekly stoppage, all gears should have attention, and, say quarterly, the copper of electrode grips should be heat-treated to render it soft and pliable. Electrical losses larger than one would imagine can be caused through this neglect.

However, it is the metallurgical upkeep which is the most important. The hearth cannot have too close an inspection after every heat, and to ensure its permanence the following precautions must be taken:—

(1) All tools and materials for repair should be at hand so that not a moment is lost after the furnace has been emptied, as the residual heat is largely relied upon to effect repairs.

(2) All metal must be removed before making any repairs.

(3) All slag must be carefully raked from the furnace, as it often hides considerable holes, besides affecting the slag in the following heat.

(4) The depth of the hearth should be gauged by a bar specially prepared for the purpose. For this purpose a chain suspended from a bar is ideal.

(5) If the hearth is a conductor and made up of layers of varying mixtures, and a hole is found penetrating into a special-mixture layer, then that mixture must be made up for the purpose of its repair. The residual heat will be insufficient to bake this. Therefore, after well hammering the repair with a heavy tool, it should be covered with lime. Coke, preferably gas coke, is charged in and arced upon until it is found to be fused. In the case of a really bad bottom a pig wash can usefully be used instead of shutting down for a general repair.

(6) At the end of each day the furnace roof should be swept.

Charging the Furnace.

The following points are worthy of notice:—

(1) If the hearth has "grown" rusty, scrap should be charged first. This is preferable to "flowing" with either sand or spar, as the action from flowing is indeterminate. If "flowing" has to be resorted to, then the author prefers the use of sand as being less drastic.

(2) If extremely light scrap is charged, it is advisable to ascertain whether the cross-sectional area of the pieces beneath the electrodes are sufficient to carry the current and make adequate contact with the hearth.

Cases have been known in low-powered furnaces where the scrap has merely fused on to the end of the electrode, and either hoisting or lowering would result in a broken electrode.

The Return of Phosphorus to the Bath.

Mr. Colin Gow, in his book on the "Electro-Metallurgy of Steel," states that it is difficult to explain the increase of phosphorus some 0.006 to 0.008 per cent. from slagging to casting, since the increase cannot possibly be due to a reduction of phosphorus from the inappreciable quantity of oxidising slag left behind after a careful skimming. The author has in his possession a series of analyses of oxidising slags made in one of the most reliable laboratories in Europe, which show that such slags may contain over 30 per cent. of metallic iron and over 0.5 per cent. of phosphorus. Now using these figures, this involves that 92 lbs. (41 kilos) of the oxidising slag would have to be left on the bath and banks of a 3-ton furnace. Now such a furnace would, according to Mr. Gow, require about 150 kilos of lime, and produce probably about 500 kilos of slag. Therefore it would require that 8.3 per cent. of the slag be left on the bath and banks. We would further point out that these slags are amongst the heaviest known to ferrous metallurgy, and are often sold for the iron contents. This being so, it is possible to visualise that they might be at slagging temperatures partially miscible with the bath, then no amount of slagging can be of avail. This latter condition is confirmed by experiments carried out by Mr. Stobie in a stationary furnace provided with a tap-hole.

This furnace was at a high level, and tapped into a secondary furnace at a lower level. After metal was melted and dephosphorised in the primary furnace, it was tapped in to the secondary furnace. As soon as slag appeared the launder, which was of Y-construction, allowed the slag to flow into a slag tub. Even in this case there was a distinct increase in phosphorus on deoxidising in the secondary furnace.

Fluidity of Electric Steels.

For foundrymen, the lack of fluidity in electric steels is a serious matter. In low carbon steel this phenomenon is specially noticeable. Fortunately, the specifications for steel castings do not demand an extremely low sulphur-content, and no prolonged refining period is necessary to reduce this impurity to sufficiently low limits. The loss of fluidity occurs when the bath is kept stewing over long periods. Thus, after slagging, the casting temperature should be reached as quickly as possible and the furnace tapped. Dr. Desch ascribes the lack of fluidity in electric steels to the absence of exothermic reactions. In converter steel they continue up to freezing temperature. That electric steel can be made very fluid is amply demonstrated by the fact that the author has on many occasions bottom-poured 120 castings from a 3-ton furnace, in two widely-separated shops, connected together by means of donkey transport.

Electric Furnace in the Iron Foundry.

The author regrets that he has had no practical experience in the commercial exploitation of furnaces for iron castings. He has, however, on many occasions melted cast iron as washing charges. It was found that owing to the lack of exothermic reactions and possibly the poor heat conductivity of cast iron at medium temperatures that the product was inclined to be sluggish and costly to manufacture. Lower voltage than is normal for steel manufacture is preferable. If fluidity cannot be gained by other means, a small dose of iron ore or mill scale, followed by a covering addition of ferro-silicon, might remove the trouble.

Heating Furnaces by Resistance.

In electric steel works carbon is generally available in four forms, graphite electrode ends, amorphous carbon electrode ends, metallurgical coke and gas coke. The poorest conductor of electricity—gas coke—should be chosen, providing that the ash is not of such a character that it will fuse too strongly on the furnace hearth.

Getting Output.

The following are a few of the factors to be considered if output is of primary importance:—(1) A mechanically-sound furnace, provided with the best refractories available. (2) Light and efficient economisers. (3) Graphite electrodes. (4) Fool-proof electrical gear. (5) A systematic overlooking of all moving parts. (6) Adequate stocks of raw materials and spare parts. (7) A control over the composition of raw materials.

XUM

Physics of Cast Iron.*

By E. Adamson (Sheffield).

Whilst it is neither possible nor necessary to go back to the old-fashioned method of making iron, it is a fact that when quality—even in steel—is required for special purposes, the very best material is produced from small charcoal furnaces such as are used in Sweden to-day.

The only possible reply to the question "why?" is that there is the selection of materials such as ores and fuel, and that it is manufactured in small furnaces well under control and at low temperatures. This is the starting point when considering quality.

It may be as well to remark here that in all blast-furnaces the conditions of smelting are oxidising,† so that any statement made upon blast-furnace practice cannot be applied in its entirety to the non-oxidising conditions of an electric furnace, which have still to be investigated, except that the principle of the influence of temperature on carbons remains.

As the output of iron increased, so did the necessity of using the small ores instead of selecting sizes, also the metallic contents of the ores available have decreased and more fuel and fluxing is now used. These factors, together with the necessary increase in the size of the blast-furnace, made regularity of working less possible, which makes the control of the blast-furnace to-day a much more critical operation than formerly, yet but for the introduction of the hot blast the modern outputs necessary for meeting international competition and modern demands would not have been possible.

It has been stated that the reduction of ore to metallic iron is a function of temperature, but this statement of fact can be carried further because the higher the temperature of working the furnace, (1) the higher the T.C.; (2) the higher the percentage of graphite; (3) the larger the size of the graphite flake; (4) the lower the C.C. and its ratio to graphite, and also on the same burden: (5) the higher the percentage of Si reduced from the ore; (6) the higher the percentage of Mn reduced from the ore; (7) the lower the S.

The above are bare statements of fact, but it is not proposed to give any detailed reasons except in the case of carbon, which controls the molecular physics of cast iron as disclosed by the fracture. It will be seen, however, that temperature also controls the percentage of Si, S and Mn in the pig-iron.

In 1906 the author stated that the precipitation of graphite was a function of temperature, and quoted Moissan with regard to graphite. In 1911 the author exhibited two totally different cooling curves from irons with practically the same T.C. and other elements, but the original fractures of irons used were different, the one being a "kishy" No. 1 hematite and the other practically a white iron. The difference in these two curves was purely a difference in primary temperatures [to which the molten metal was raised.—ED.], but the significance of their difference did not appear to be understood, for, as a matter of fact, the fundamental principle underlying the difference was the basic one between sound and unsound castings. In the same paper he referred to three kinds of crystalisations of free carbon in pig-iron.

Again, in 1912, before the New York Congress of the International Testing Association, the author stated that carbon was the real controlling factor in pig-iron, and was itself controlled entirely outside of chemical composition by temperature and by methods of manufacture, otherwise by physics. Mr. Walter Wood, perhaps the most ardent American advocate, who visited England in 1911,‡ urging British iron-masters to grade by analyses, in his reference to the author's statement at that meeting, said: "There is more wisdom in this suggestion than most of us know how to handle or practically to make use of, but it is something about which future developments will undoubtedly group themselves." Time has shown that this has proved correct.

In 1906, and even in 1911, the writer was looked on as unorthodox, to use a mild term, but the fact that more notice is now being taken of carbon and less of silicon as the controlling factor in cast iron is sufficient proof of the correctness of his early statements. In fact, many large concerns are giving more practical attention to carbon, and only recently Mr. Smalley, before a meeting of the Institution of British Foundrymen in Sheffield, referred to "grain refining." No doubt the chemist, who appeared to have the idea that the author was running a campaign against the laboratory will perhaps now realise that the chemistry of cast iron, whilst necessary, is the minor and not the major part of the study of this "mysterious" science.

First of all, what is carbon? This is a difficult question to answer in a single sentence, as there is nothing which has so many modifications. The following, however, are a few:—Sugar carbon, charcoal, lignite, coal and some of its many products, graphite in its natural and synthetic states and diamonds.

From sugar carbon, by means of an electric furnace, Moissan has produced synthetic graphite and also some diamonds as a function of temperature and pressure, and in trying to understand this it must be remembered that by means of an electric furnace temperatures up to 4,000 deg. C. are now available to the chemist and metallurgist.

Moissan's Conclusion.

The keystone work on carbon by Moissan does not appear to be well-known. He produced graphite in contact with metals at varying temperatures, the most important, so far as we are concerned, being iron. His work in several respects confirms the work of others, such as Le Chatelier and Lazi.

The following are some of his very practical conclusions:—

(1) The stability of graphite in contact with metals, particularly iron, increases with the temperature to which it has been subjected.

(2) A simple rise in temperature causes graphite to be less easily attacked by oxidising agents.

(3) All graphites produced at high temperatures by dissolving carbon in a given metal swelled under the action of concentrated nitric acid.

(4) This swelling is proportional to the temperature to which the graphite has been subjected.

(5) The swelling action takes place at a temperature which varies between 165 and 175 deg. C., even *in vacuo*.

(6) Moissan states that one is led to look for a *crystalisation of carbon in molten iron* under pressure, as on sudden cooling the iron contracts violently and the carbon passes from a density of 2 to a density of 3.5.

(7) As far as silicon is concerned, no research has been systematically prosecuted and the action of silicon on cast iron has not been clearly determined.

(8) Iron dissolves a considerable quantity of carbon, but loses its fluidity and becomes pasty.

From the foregoing statements the following fundamental principles are confirmed in blast-furnace practice, but are slightly modified by the presence of other impurities:—

(*a*) The T.C. in the pig-iron is a function chiefly determined by temperature and time.

(*b*) The different characteristics of free carbon or graphite are also a function chiefly of temperature and time.

(*c*) The precipitation of free carbon *from molten or cooling metal* is also a function chiefly of temperature and time.

The Blast-Furnaces and its Products.

The modern blast-furnace cannot be worked with absolute regularity of temperature, etc., because there is no absolute control of the chemical composition or even the physical characteristics, such as size and condition of the minerals charged, or of the moisture they contain. These anomalies cause considerable variation of temperature inside of the blast-furnace, and especially when it is working

* Extracted from a Paper presented to the West Riding of Yorkshire Metallurgical Society.

† This statement requires amplifying before being accepted.—ED.

‡ Apparently a Chronological error has crept in.—ED.

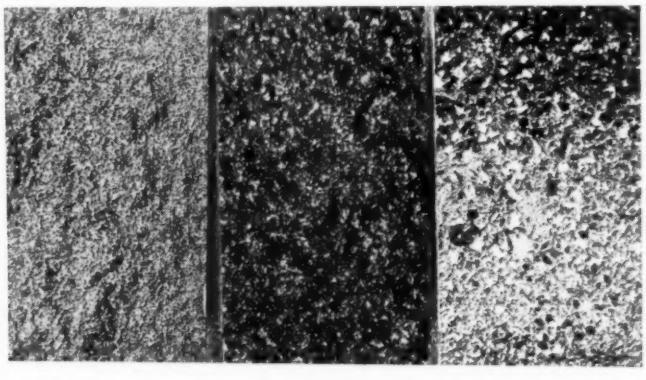
very cold, it is liable to produce what are known as off-grades of pig-iron, such as mottled, white, chilled iron, etc.; the last-named, however, is usually due to some sudden mishap. Some of these freak irons are of great technical interest, but as we are chiefly interested in grey iron suitable for the iron foundry and engineering requirements, it is proposed to confine the discussion to commercial foundry irons.

This influence of temperature is anticipated by Sir Isaac Lowthian Bell in his book.

There are five distinct classifications of fractures produced at different temperatures: (1) mottled; (2) close grey; (3) a grey "star" crystal or scattered; (4) a grey open No. 1, and (5) silky. With the first and last foundrymen are not particularly concerned, and of the grey fractures, the close grey is produced under low temperature conditions, the star crystal at medium and the open grey at high temperatures. For the purpose of easy illustration they are shown in Fig. 1.

Fig. 2 is an unetched specimen showing a "star" crystallisation of graphite. Incidentally, when one sees what are known as graphite flakes under the microscope, it is really only empty hollows indicating where the free carbon has possibly been.

Experience shows that the smaller the formation of graphite in cast iron the closer the fracture, and the stronger the iron; also the more open the fracture, that is, the larger the flakes of graphite, the weaker is the iron. Probably no one will dispute this statement, nor will anyone deny that if only an open No. 1 iron is charged on to the cupola the castings will not be close-grained and sound; or, conversely, if a naturally close-grained iron is charged on to the cupola, wether high or low in silicon, the resulting castings will not be very open and porous as if a No. 1 iron had been charged. The reason is very simple, namely, the character and condition of the graphite in the pig-iron charged.



Fine Graphite. Star Graphite. Flake Graphite.

Fig. 1.

Fig. 2.

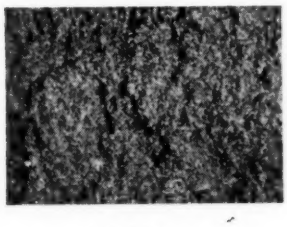


Fig. 3.

Fig. 4.

Probably few founders will have had the opportunity of examining the possible crystallisation of graphite between these two extremes, namely, the fine or amorphous and the large flake, but the "star" crystal of graphite, to which the author called attention in 1911 before the Iron and Steel Institute, is an important consideration, because it is found when iron is produced at medium temperatures it also formed under very slow cooling conditions, and also when iron has rapidly cooled from high temperatures as in the following cases:—

(*a*) Slow cooled overnight under molten iron a white fracture produced "star" crystals the following morning, as shown in Fig. 3.

(*b*) An electrically-produced pig-iron, as shown in Fig. 4 of : T.C., 4.28; Si, 0.28; S, 0.05; P, 0.009.

and Mn, 1.72 per cent. cast into a chill showed a "star" crystal even on the face of the chill, theoretically an impossibility.

Moissan and other scientists claim several forms of free carbon, such as temper carbon, amorphous carbon, graphite, etc. From one of his experiments Moissan concludes that the alterations of the character of amorphous carbon to graphite is a question of temperature, and he wonders if amorphous carbon can be produced from the refractory graphite formed as a function of temperature.

The conclusions which the author has reached in connection with the use of pig-iron in the foundry are that once graphite is formed at a high temperature in the blast-furnace, its influence remains throughout foundry operations to the final casting, and can only be materially modified by careful mixing so as to break up the large flake. For example, assuming a No. 1 iron containing T.C. 3.50 per cent., mostly graphite, is mixed with 50 per cent. of steel scrap, the average T.C. on the charge will be about 1.75 per cent., but in the molten metal in the ladle there will be T.C. 3.00 to 3.25 per cent., therefore between 1.25 and 1.50 per cent. of carbon has been picked up in the cupola at a much lower temperature than that at which the original graphite in the pig-iron was formed. The probabilities, based on actual experience, are that the character of this high temperature graphite will be shown in the metal in the ladle, if cast into a test bar, to contain a large quantity of the "star" crystal graphite along with the smaller form of free carbon. In other words, the percentage of, say, 1.50 to 1.75 per cent. high temperature graphite is not sufficiently high to separate out in the cold metal in its original large flake form, even when assisted by the remaining 1.25 to 1.50 per cent. low-temperature graphite picked up in the cupola.

Phase Rule not always applicable to practice.

On the other hand, unless suitable means are taken for destroying the influence of the large-flake graphite, the whole of the carbon, as suggested by one of the author's cooling curves, will not go into solution on remelting the iron, and the cooling metal will therefore begin to solidify at a higher temperature, which will not conform to the phase rule of the iron-carbon diagram. This latter statement, it is feared, will not be generally accepted, but Dr. Carpenter, in the discussion on the author's 1911 Paper, agreed that the phase rule relating to solidification could not always be applied to works practice.

Moissan (conclusion 6) looked for a crystallisation of carbon in molten iron, but states that between 1,100 deg. C. and 3,000 deg. C. molten iron behaves as a solvent dissolving more carbon as the temperature rises, as he found that when cooled between 1,700 deg. C. and 1,100 deg. C. the iron gave off a quantity of crystal-graphite. The author, however, considers from Ruff and Goecke's experiments on the saturation of carbon and iron, which agree with his own works observations, that it is more probably that Moissan's views in this respect are correct up to a given maximum temperature, but beyond that temperature the character of the graphite formed will be such as will not go into solution, otherwise how could diamonds be formed, and graphite on rapid cooling.

Two examples from Ruff and Goecke's work are here given:—

	T.C.	G.C.	C.C.	Sp. Gr.
(*a*) 1,800 deg. C.	6.62	2.41	4.21	6.85
(*b*) 2,220 deg. C.	9.64	3.31	6.29	6.27

These two examples have been selected because at 1,800 deg. C. these investigators get a T.C. equal to the theoretical carbide percentage (Fe_3C = 6.66 and Fe_2C = 9.68 per cent.), yet on rapid cooling practically 40 per cent. of the carbon in the cold iron is graphite, and in the second case at 2,220 deg. C., where these investigators obtained T.C. 9.64 per cent. on rapid cooling about 40 per cent. of the carbon in the cold specimen was graphite and the remaining C.C.—so-called—is practically the theoretical percentage of carbon in the carbide.

Had Moissan been correct in regard to all carbon being in solution, the whole of the carbon in these two cases should have been C.C. and the specimens should have been perfectly white in cooling rapidly. Both, however, contained a large proportion of graphite, showing, what photo-micrographs would have proved, that the crystallisation was different in the two specimens. The difference in the condition and percentage of carbon, however, combined with the difference in specific gravity, will be sufficient proof.

The iron-carbon diagram gives the eutectic as 4.25 per cent., and in the early days of technical knowledge this has been known as the saturation point of iron and carbon. The equilibrium diagram has, however, been built up on purely laboratory work, and is perfectly correct for the conditions under which it was carried out. Ruff and Goecke's work on the saturation point of iron and carbon and the author's two cooling curves, which were suggested by close contact with the working of the blast-furnace, were published in the same year, 1911, and they both confirm what is explained by Moissan's work, that under high temperature conditions the T.C. which iron is capable of taking up does not all go into solution, whether it is under laboratory conditions of the electric furnace and pure iron-carbon alloys or when selections of pigs are made from the products of the blast-furnace.

Volume Considerations Important.

The practical use of this recognition to the foundry is that if the carbon in materials used is in such a condition as will be taken up in solution, the phase rule, modified, of course, by other impurities present, will apply and the molten metal will solidify at the lowest possible temperature, but if the carbon is in such a condition as will not all go into solution, then the phase rule cannot be applied to cooling except to that percentage of carbon which is in solution as shown by the two cooling curves mentioned. "A" curve (T.C. 4.20 per cent.), had all carbon been in solution, would have solidified at a lower temperature than "B" curve (T.C. 3.90 per cent.), because it contained 0.30 per cent. more T.C., but as a matter of fact, "A" curve, containing the higher T.C., solidified at practically 2 per cent. carbon steel. The Si, S, P and Mn were practically the same. In considering the influence of carbon, the percentage by weight only has usually been taken, but the volume percentage is probably five times this, and therefore with T.C. 3.50 per cent. the influence must be measured by approximately 17 per cent., or about one-sixth of the total volume, which will perhaps the more easily explain its predominant influence.

Before leaving the consideration of the saturation of carbon and iron, which has such a very great influence on the structure of cast iron, it might be well to state incidentally that when using pig-iron produced in the blast-furnace it is acknowledged that it is wise to keep the T.C. in the iron to be poured into a casting as low as possible, although it may be known that one of the reasons of the advisability of this is to make as sure as possible that all carbon is in solution, the other reason being, as is well known, that the lower the T.C. the slower the separation of graphite and its growth to the full flake, thereby assisting in giving close grain and slightly higher tests, but because of this it is not wise to argue that high T.C. will not give tests, for in an electrically-produced pig-iron with T.C. nearly 4 per cent. and silicon about 2.5 per cent. tests have been shown, the author giving 20 tons tensile and over 40 cwts. transverse on a bar 1 in. × 1 in. × 12 in. The specific gravity of this was 7.35, which suggests an intensely close fracture. Quite recently also a piece of Swedish iron has come into the author's possession with T.C. 4.63 per cent. and silicon about 0.50 per cent., and although the slabs were a bare 2 in. thick, they were most difficult to break with an ordinary sledge hammer. The first of these was electrically produced and the second may have been also.

Quite recently there has come into the author's possession a piece of common foundry pig-iron of T.C. 4.50 per cent. and silicon 4.83 per cent., both of which figures have been checked three times, and the fracture a very grey open No. 1. Had the saturation percentage of Fe and C. been 4.25 per cent., modified by other impurities present, this pig should have been T.C. 2.30 per cent., or about half the actual percentage. Granted this is not usual, but we are discussing the possible actual saturation, and this is used to illustrate how impossible it is to control carbon in the blast-furnace;

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in fact, one wonders if it is necessary. In a previous investigation the author encountered castings containing T.C. 4.50 per cent., whilst the irons charged on the cupola were T.C. 3.00 per cent.

In conclusions 3, 4 and 5 Moissan speaks of intumescent or swelling graphite due to the temperature to which graphite has been raised in contact with iron. After Moissan's experiments it can hardly be denied that this statement is accurate, and it certainly furnishes a substantial and logical explanation practically as to why a No. 1 iron is porous and of a much less specific gravity than a closer iron. It also furnishes a logical explanation of the difference in the author's two cooling curves and why they strike at their fundamental and practical value, for the sample of cooled iron from "A" curve was perfectly open, showing primary crystallisation, whilst that from "B" curve was perfectly close in fracture. Intumescent graphite also gives a logical explanation of an open iron causing internal draws.

Moissan's purely academic research has, it will be seen, a very practical application to metallurgical operations in the blast-furnace and the foundry, for the crystallisation of graphite is the greatest factor in the molecular structure of cast iron, and this is influenced by primary and again further modified by secondary temperatures, as also by chemical composition outside of carbon.

Taking pure white iron as a base and adding thereto varying percentages of ferro silicon, the white iron will eventually become perfectly grey, but by continuing to add silicon, even to 3 per cent., if the metal is normally cooled, the openness of the fracture is not materially altered. A similar phenomenon can be stated of phosphorus, when added to grey iron produced in this way, for P is a softener in that it assists in the precipitation of carbon, but when added in this way it will tend to close the grain of the iron. Mn, on the other hand, when added to grey iron in the above manner, will tend to close the grain, but when added in the blast-furnace it has the opposite effect, for temperatures are increased and the fracture tends to be more open.

That is to say, the influences on the molecular physics of cast iron of the addition of Si, P and Mn, by adding these in crucible melting, are not strictly applicable, when these are originally added in the blast-furnace where the temperature conditions are totally different.

Metallurgists are wisely beginning to look first to structure for tests, rather than to chemical composition. Structure itself is subdivided, for in addition to the varying percentages of impurities, even a fine structure may be what the practical man calls "dry," and not therefore as strong as another iron of apparently the same structure. This condition again appears to be physical, for this "dryness" of fracture can be overcome by the addition of a small quantity of rich "kishy" iron.

Summary.

For a long period the chemical composition of cast iron was believed to control the physical properties and tests, whether the pig-iron was made in a cold or a hot blast-furnace. Then came a period of the suggestion of the microscope in the foundry, which it was then thought would, to a large extent, do away with chemistry, being quicker in disclosing the approximate C.C., Gr, S, P and Si from the percentage of C.C.; that, however, was not possible. Now, however, we are well into the period when the structure, *i.e.*, the closeness of grain or "grain refining" is being considered of greater importance than chemical composition, and again in his Paper previously cited Mr. Smalley confirms the author in saying that he had not been able to associate the C.C. content in grey iron with either strength or texture.

There is no doubt that structure in pig-iron is primarily controlled by the temperature at which the iron was originally produced, and further, the secondary influence on structure is mass, but primary temperatures are of the greatest importance, and if by explaining this in some detail the author has elucidated the dominating influence of the condition of carbon on the molecular physics of cast iron, he is simply satisfied.

Molten Ferro-Manganese.

By Frank Hodson.*

It is now generally agreed that it is very desirable to make molten ferromanganese additions to open-hearth and converter steels rather than to cold unmelted metal. Bessemer first recommended this, but the advent of the electric furnace has made it possible to do this in a simple and efficient manner. Ferromanganese is not an easy alloy to melt and handle when required intermittently, and it is probable the difficulties with the melting equipment that has prevented wider use of molten manganese. A properly designed electric arc furnace, with its low power fractor, is used for previously experienced and insure at a low operating cost supplies of real hot liquid ferromanganese.

The effect of such hot ferromanganese on steel either just before pouring it or in the ladle is very much more pronounced than when the cold alloy is added. In England, where several such furnaces have been operated for some time, and in Germany, where the complicated induction furnace, with its lower power fractor, is used for the same purpose, it has been found that the actual amount of ferromanganese used can be reduced 30 to 40 per cent. in favour of the molten process. Coupled with this, the resultant steels have been freer from gases, occluded oxides and slag, and the waste and rejections have been much less.

This saving in actual amount of ferromanganese added to the charge is probably due to the fact that when adding the molten alloy it is entirely taken up by the steel, and no part of it is lost in the slag or remains undissolved. It has also a greater deoxidising effect than cold alloy and there is no cooling of the bath. There is no dissolving to be done, and if the molten ferromanganese is added in the ladle it can be poured without loss of time.

The resultant steels roll and forge more easily than when ferromanganese is added cold, as it is safe to say that if 0.50 per cent. manganese were the minimum amount to enable a given steel to roll probably if molten ferromanganese were substituted 0.35 to 0.40 per cent. would give a steel that would roll easily. In addition to better quality of steel, to less amount of ferroalloy, and to absence of melting loss, additional savings can be made by the use of manganese ore, inferior fines and low grade ferromanganese. All these can be used in the electric furnace. In experiments made on a "Greaves-Etchells" furnace as much as 25 per cent. of the charge was added in the form of manganese ore. The metallic melting loss rarely exceed 3 per cent.

With proper metallurgical manipulation of ferromanganese, it seems highly desirable to use an electric furnace with a large open bath rather than a restricted channel as in the induction furnace, and also one of which there is a circulation from the bottom of the furnace. It was found when only top heat was applied that the manganese had a tendency to segregate out and sink to the bottom, where it would stick. When the bottom connection on the furnace was cut in segregation ceased and the metal was uniform throughout in temperature and composition.

The voltage required on melting ferromanganese differs considerably from steel, and in order to keep a steady arc and, if necessary, to hold the furnace on low power input, it is important to have a furnace in which each electrode operates independently and which can keep steady arcs with only 20 to 25 per cent. of normal electrode load. A 4-electrode furnace with one phase attached to furnace hearth, giving slow circulation of metal from the bottom, is ideal for ferromanganese or for any alloy or high-grade steel. Steel makers will undoubtedly appreciate the benefit to be obtained from use of molten ferromanganese, and as the process involves an actual saving of money, it will no doubt receive the attention it deserves from progressive management.—*Iron Age.*

It is proposed to establish an engineering society for Walsall and district.

* President Electric Furnace Construction Co., Philadelphia.

A Criticism of the Physics of Cast Iron.

By J. E. Hurst, Carnegie Scholar.

In the article entitled "The Physics of Cast Iron" Mr. Adamson is apparently concerned in emphasising the importance to be attributed to the carbon in its influence on the tensile and transverse strength of cast iron. The importance of carbon, its quantity, condition and distribution in grey cast iron cannot be over-estimated in this connection. It must not be forgotten, however, that all experience and investigation in connection with cast iron have shown that the two latter features, viz., condition and distribution, are largely governed by the remainder of the composition and the conditions of cooling to which the cast iron has been subjected.

Mr. Adamson studiously avoids direct reference to these features—the rate of cooling and the remainder of the composition, although what he describes as "temperature and time" may amount to the same thing in the end as rate of cooling.

In a Paper under this title and which attempts to elucidate some features of the molecular physics of cast iron, Mr. Adamson has made certain misstatements of fundamental physics and physical chemistry which are liable to confuse the student foundryman and which should not be allowed to pass without comment. The bald statement that "in all blast furnaces the conditions of smelting are oxidising," followed later by that concerning "the reduction of the ore to metallic iron," has already received notice on the part of the Editor. In a Paper purporting to deal with molecular physics the inclusion of charcoal, lignite, coal *and some of its many products* as modifications of carbon is a mistake. Later on to infer the possible crystallisation of graphite in the amorphous state and the description of the cast iron "containing the higher total carbon" which "solidified at practically 2 per cent. carbon steel" are amongst some of the loose misstatements which should be carefully read by the student.

Moissan's Investigations.

From the student's point of view, in this Paper it is unfortunate that Mr. Adamson has based so much of his arguments on the work of Moissan, who, after all, was more concerned, so far as the writer remembers, with trying to make diamonds than to elucidate the molecular physics of cast iron. The work of Turner, Wust, Goerens, Charpy, Guillet, Hatfield, Howe, West and many other investigators, who have sought to correlate the composition, constitution and properties of cast iron, will repay the study on the part of those who are interested in these matters far better than the work of Moissan.

Mr. Adamson attempts to show that the character, condition and distribution of the carbon is mainly influenced by the temperature of production of the pig iron, and that its influence may under certain conditions so modify matters as to prevent the free graphite from all being re-dissolved in the molten metal on remelting in the cupola. It is also through this phenomenon that the effect of subjection to a high temperature in the blast furnace retains its influence throughout subsequent foundry operations on the pig iron to the final casting.

Reasoning from Cooling Curves.

The evidence on which Mr. Adamson bases these conclusions might be summarised as consisting of two cooling curves exhibiting certain peculiarities. These might be termed the quantitative evidence and the certain samples of pig iron exhibiting further peculiarities might be considered as the qualitative evidence.

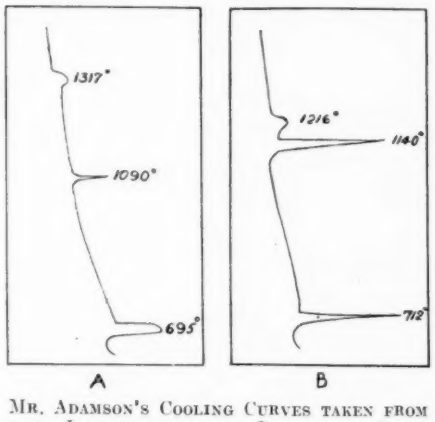
The writer has long been particularly interested in the two cooling curves, and if the two curves referred to are the same as those previously published by him, the writer cannot agree with Mr. Adamson that the two irons had "practically the same total carbon and other elements." Also from a full consideration of these curves as far as possible with the published data available they do not form conclusive evidence to justify the conclusions drawn by Mr. Adamson. The analyses of these two samples A and B taken from Mr. Adamson's previously published data regarding these curves are as follows:—

(A) TC, 4.20; Gr, 3.62; CC, 0.58; Si, 1.02; Mn, 0.53; S, 0.018, and P, 0.022 per cent.

(B) TC, 3.90; Gr, trace; CC, 3.90; Si, 1.04; Mn, 0.22; S, 0.010, and P, 0.018 per cent.

The initial fracture of A was a No. 1, and that of B practically white. The fracture at the finish of the former was grey-porous and the latter close grey.

The sample A was a hematite pig iron, the virgin product of the blast furnace, whilst sample B was obtained by the addition of ferro-silicon to Swedish white iron. The cooling curves were taken from a temperature of 1,500 deg. C., a temperature of 300 deg. C. higher than necessary to obtain liquid metal. The samples were melted in crucibles pre-



Mr. Adamson's Cooling Curves taken from the Journal of the Iron and Steel Institute, 1911.

sumably under the same conditions. The cooling curves have been interpreted by Mr. Adamson as showing that only about one-half of the total carbon was in solution in the sample A, the other half being in suspension, whilst in sample B the whole of the carbon was in solution.

The facts to be noted on considering these two curves are as follows:—

(*a*) The occurrence of a primary arrest point in both instances at a temperature of 1,317 deg. C. in sample A and 1,216 deg. C. in sample B.

(*b*) The occurrence of a final solidification arrest point in both instances at a temperature of 1,090 deg. C. in sample A and 1,140 deg. C. in sample B. The magnitude of this solidification arrest is considerably greater in the case of sample B than sample A.

(*c*) The pearlite transformation occurs in sample A at a temperature of 695 deg. C., and is considerably less in magnitude and lower in temperature than the transformation in sample B, which occurs at 712 deg. C.

The increase in the amount of graphite, the lowering of the pearlite transformation in sample A are completely in accord with the classical experiments of Hague and Turner (J.I.S.I., 1910), who found an exactly similar occurrence with the presence of 0.5 per cent. of manganese. The position of this transformation in sample B with 0.22 per cent. manganese is also in accordance with what one would expect from the above-mentioned research (Q.V.).

The lowering of the solidification arrest in the sample A is remarkable. In the case of sample B the temperature of 1,140 deg. C. is in accordance with other work. Whatever reason this be attributed to, it has no bearing on the question at issue.

The initial arrests occurring at 1,317 deg. C. and 1,216 deg. C. in samples A and B respectively

are the most important features. Since sample B is practically of eutectic composition, the occurrence of a double solidification arrest would not have been expected. It is unfortunate that no analysis of the sample was taken after the remelting, as the occurrence of this point leads one to expect some change in the carbon content. Since this iron is a white iron and the question of the solution of graphite does not arise, the only change in carbon content which would account for this is a loss of carbon, possibly as a result of oxidation during remelting. The only other explanation which might be given of the occurrence of this upper point in sample B is on the lines of that given by Andrew (Carnegie Memoirs, J.I.S.I., 1916) (Q.V.), who noticed a similar case in connection with certain samples which had been efficiently quenched previous to remelting to retain the white structure. (A treatment to which sample B might have been conceivably subjected.)

With regard to the primary arrest in sample A at 1,317 deg. C., a simple explanation is not readily forthcoming unless some change in carbon content on remelting prior to taking the cooling curve is assumed. The sample A contains carbon in excess of the eutectic perentage, and from an inspection of the liquidus surface of the iron-carbon-silicon diagram (Gonterman, J.I.S.I., 1911) it will be seen that the temperature of 1,317 deg. C. is considerably higher than one would expect on the assumption that the carbon content suffered no change. From this same diagram it will be found that in alloys containing 0.9 per cent. silicon (a percentage very close to A), the carbon content of the alloy showing an upper arrest point of 1,317 deg. C. as in sample A would contain only about 2.75 per cent. carbon. This alloy would give a cooling curve similar to A. It is reasonable, therefore, to conclude that the upper arrest on the cooling curve of sample A at a temperature of 1,317 deg. C. indicates that the carbon content has been reduced to this figure.

The reduction in total carbon content can be accounted for either by loss due to oxidation during melting in the crucible or it will be allowed by a failure of a portion of the carbon to redissolve as alleged by Mr. Adamson. The final and, incidentally, the most conclusive, evidence either way would have been the results of the analysis *after* taking the cooling curves. In the absence of this information, the writer would be inclined to believe that a loss of total carbon has been experienced in remelting, and that this is responsible for the upper arrest point.

This belief appears to be confirmed on the following grounds: (1) The small magnitude of the *final* solidification arrest in sample A as compared with sample B, and supported by (2) the high temperature to which the sample was raised on remelting in a crucible presumably unprotected by charcoal, and (3) that with the comparatively slow rates of cooling from this high temperature one would expect any undissolved graphite to rise to the surface as kish.

These curves as they stand therefore afford us conclusive evidence on the point raised by Mr. Adamson, that a portion of the graphite in sample A is not redissolved on remelting, and they appear to show that the sample was somewhat oxidised on remelting with a resulting total loss in a portion of the carbon.

Graphite Percentage Useful.

Mr. Adamson's further qualitative evidence in the shape of certain special samples of pig-irons which have, contrary to expectation, been found to contain free graphite, cannot be considered deeply with the very scanty data available regarding the investigations on the samples. It is unfortunate that in the case of the electrically produced pig-iron Mr. Adamson does not give the actual amount of graphite present when stating the composition. The microphotograph Fig. 4 is as it stands very doubtful evidence on such an important point. The photograph appears to have been taken from very near to the edge of the specimen, and under these circumstances the marking shown may be graphite or it may be other inclusions, detached crystals, or even scratches.

None of the evidence advanced by Mr. Adamson can be taken as conclusive proof that the molecular character of the graphite is modified as a result of the high-temperature conditions under which it has been absorbed in the blast furnace, or that it is possible for some of the graphite to fail to be absorbed on remelting ordinary grey irons other than those having carbon in excess of the eutectic composition. This is unfortunate, as if it were the case it would appear to be easily capable of direct proof.

It is, however, an observed fact that the temperature of production of the pig-iron in the blast furnace has a marked influence on the character of the final pig-iron. Apart from the effect of any modification in the composition of the pig-iron other than the carbon, this influence can be sufficiently explained by the variation in the rates of cooling of the pig-irons in cooling down from these various high temperatures without having recourse to the assumption or inference of an actual modification in the free graphite.

The German Iron and Steel Industries.

Since obstacles were placed in the way of the export of iron and steel from occupied to non-occupied Germany, it is stated that imports of bars, sheets and other rolled products have begun from Czecho-Slovakia and Austria. The prices charged by makers in these countries have been raised to double the rates which prevailed as the world's market prices prior to the occupation of the Ruhr.

The Foreign Trade Bureau for the iron industry has been transferred from Münster to Berlin, in so far as it deals with import permits. Applications in regard to export licences continue for the present to be handled in Münster, although this branch also will shortly be removed to Berlin.

French and/or Belgian military authorities are reported to have paid visits on March 10 to the August-Thyssen works at Hamborn, the foundry department of the Gelsenkirchen Mining Company at Hüllen and the Phœnix works at Hoerde. The authorities were accompanied by engineers, who sought to obtain information concerning stocks of raw materials and lists of orders and to make an inspection of the works. A similar investigation has since been made at the Düsseldorf works of the Rhenish Metalware and Machinery Company, where locomotives and wagons have been requisitioned.

A banking partnership concern, under the title of P. A. Meckel & Company, has been formed in Berlin with a capital of 600,000,000 marks, to maintain vital connections between German economic interests and trade and industry in Austria, Hungary, Czecho-Slovakia, Poland, Russia, Yugo-Slavia, Rumania, and Bulgaria. Among the leading partners are mentioned the names of Herr Mannesmann, of Remscheid, and Herr Ernst Röchling, of Mannheim.

The Rasselstein ironworks, which is one of the oldest rolling mills and occupies the leading position in the tinplate market, has been converted from a private into a public company, under the title of the Rasselstein Ironworks Company, of Rasselstein, near Neuwied.

The production of basic Bessemer pig-iron in the Saar in 1922 is returned at 1,154,638 tons, the monthly outputs in the final months slightly exceeding the average of 1913. The tonnage of basic Bessemer steel made was 981,326, that of open-hearth steel was 274,278, and that of electric steel was 6,424 tons. The number of workmen employed at the five works in the Saar in October, 1922, was 32,230.

Contracts Open.

Bridgend, April 9.—For providing and laying about 423 yards of 4-in. diameter cast-iron piping, for the Mid-Glamorgan Water Board. Mr. E. W. Davies, superintendent and manager, Water Board Offices, Bridgend. (Fee, £1 1s., returnable.)

Johannesburg, April 23.—Piping, etc. The Municipal Council of Johannesburg are inviting tenders for the supply and delivery of wrought-iron piping and fittings. The Department of Overseas Trade (Room 47).

Machynlleth.—Supply of about 425 yards of 3-in. steel gas mains, spigot and socket joints, lapped and coated with a solution, in long lengths. Manager, Gasworks, Machynlleth.

German Customs Surcharge.—The gold premium on Customs duties paid in paper marks has been fixed at 524,400 per cent. for the week from March 21 to 28 inclusive.

Institution of British Foundrymen.

LONDON BRANCH.

The January meeting, held under the chairmanship of Mr. Wesley Lambert, was of an educational character. Mr. G. Patchin, head of the metallurgical department of the Sir John Cass Technical Institute, was the lecturer for the evening and took for his subject microphotography and equilibrium diagrams.

THE PRESIDENT asked Mr. G. Patchin to deliver his lecture on "The Interpretation of Photo-Micrographs and Diagrams in Connection with Foundry Alloys." The subject, he said, would appeal to all those who were progressive, and he did not think anybody would have turned up at the meeting if they were not progressive. Unfortunately, however, amongst foundrymen of to-day there did not seem to be that keenness to follow up the inner science and methods. The President remarked that Mr. Patchin was associated with the Royal School of Mines, and had taken a very great interest in metallurgy for many years.

Interpretation of Photo-Micrographs and Diagrams.

MR. PATCHIN, at the commencement, said he was uncertain whether the order in which the title had been placed was correct or not. It could be very well debated as to whether one should interpret diagrams before interpreting micro-photographs. He was perfectly prepared to acknowledge that in the early days of this subject we had started interpreting photographs, and it was not until a number of years later that we were able to ascertain the rules, for, after all, the diagrams represented the rules whereby we could more accurately interpret the results obtained by micrographic examination. But it was possible to get a great deal of valuable information by the microscope without the use of diagrams; in fact, the diagrams would not help in interpreting some of these things. They were extraneous to the diagram, so that the microscope was useful in conjunction with the diagram and separately. In illustration of that, Mr. Patchin threw a few slides on the screen showing how the microscope could be used apart from diagrams, which latter held such a terror, not only to a number of foundrymen, but, unfortunately, to a number of students of general metallurgy. These were micro-photographs of metals cast in different ways, showing various types of structure, of which, so far as he was aware, no diagram would give any explanation. Photographs were shown of a piece of 70/30 brass which, after casting, had been severely cold worked, and a considerable amount of deformation of the crystals was apparent. The first result of annealing that piece of metal was shown to be a recrystallisation. Therefore, the degree to which cold working and annealing had been carried on could be ascertained by photo-micrographs. The result of more severe annealing produced what was a characteristic of a 70/30 brass, namely, twinning, and that was another case in which the microscope was of real value. It would enable one to determine within relatively fine limits the composition of an alloy, especially if it were merely a binary alloy. Further slides showed how the production of slip bands was disclosed by micro examination without the use of diagrams. Again, foreign bodies in metals and alloys could be readily ascertained by microscopic examination, and slides illustrated the presence of slag patches in wrought iron and in steel. Mr. Patchin explained that in the production of wrought iron the metal never came to a molten condition, but was in a plastic state, making it easy for slag to be included. With regard to steel, he supposed that nearly every sample of steel contained, not slag—although some people might class it amongst the slags—but minute quantities of manganese sulphide, and sulphur showed up under the microscope in little pools. That sulphide of manganese was taken account of in the diagrams, but it was an alien substance so far as steel was concerned, and the microscope was exceedingly useful in determining its presence.

Non-Ferrous Application.

Turning to the non-ferrous side, a slide illustrated the presence of lead in brass. The lead did not alloy with the constituents of the brass, and was distributed in small patches throughout the metal. It was a 60/40 brass, the lead content being about 1 per cent. The sample, properly polished, and examined without etching, revealed the lead inclusions, which in this case were not alien, the lead having been specially added. Another slide, which was in connection with some work which Mr. Patchin had carried out both independently and in conjunction with Professor Banister, showed the effect of various metals of the platinum group on silver. It was an attempt to alloy iridium with silver, and the micro-photograph indicated that the iridium had settled down to the bottom of the molten metal and had collected in a series of very fine grains.

In amplification of that part of his lecture in which he had dealt with the degree to which a metal had been annealed or normalised, he showed a micro-photograph of a piece of shell steel containing something like 0.5 per cent. carbon. The two constituents shown were pearlite and ferrite. The mechanical test of a sample of steel such as that shown would not be altogether satisfactory, for the reason that ferrite was of a very coarse character. Examination under the microscope immediately led one to the conclusion that the metal either required further normalising or annealing—for, after all, "normalising" was a term which could be used to express an operation which represented partial annealing. If such a sample as that shown were heated to, say, 820 or 850 deg. C. for half an hour, and allowed to cool moderately slowly, a very great difference in the structure of the metal would be found. Another slide showed the same steel, cut from the same shell, normalised at the temperature mentioned, and it was seen that the ferrite areas were very fine, and in the form of a network, and the metal was much stronger as the result of the breaking up of the coarse ferrite and the formation of the network.

Another direction in which the microscope could be usefully applied was in the finding of faulty metals. Three slides were shown of phosphor bronze, the first showing a spongy metal. He would not say that it was possible to ascertain the sponginess by direct observation, because he had not made the slide, but it could be seen from the slide that the metal was spongy, there being cavities. A section of the same piece of metal photographed at a much higher magnification again showed areas due entirely to sponginess. The third slide showed a sound piece of phosphor bronze, in order to illustrate the difference between the spongy and the sound, and in the latter the cavities could not be seen. All those illustrations gave some indication of the way in which it was possible to utilise a microscope without having gone into the subject of the constitution of the alloy and the formation of the diagram connected therewith.

How Cooling Curves are made.

Mr. Patchin then dealt with fusibility and equilibrium diagrams, which really represented the rules by which one generally interpreted micro-photographs. He illustrated on the blackboard the general methods used, explaining that they were obtained by means of cooling curves, which cooling curves were obtained by the use of pyrometers. The best way to understand what a pyrometer was was to think of it as being a thermometer which would record very high temperatures. Dealing with the rate of cooling of metals, he said that the rate of cooling was dependent upon the rate at which the heat was given out into the atmosphere or conducted away by the body with which the hot metal might be in contact, but under all conditions a heated body would not cool at a uniform rate. If a mass of molten metal, tested with a pyrometer every half-minute, cooled at a uniform rate, the "curve" would be a straight line. As a matter of fact, the rate of cooling was always more rapid when the metal was hotter, and he plotted a typical curve of a pure metal on a diagram, showing temperature vertically and time horizontally. The curve descended regularly to a certain point, and then suddenly proceeded almost

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horizontally, showing that the temperature for a period remained practically constant. At the point of change the metal was solidified, and the explanation of the change was that in the actual operation of solidification heat was evolved, and the evolution of that heat maintained the temperature for a marked period. After that period the temperature again fell normally and regularly, until atmospheric temperature was approached. Eventually the curve became very flat, and a considerable time was taken to fall the last 100 deg. That diagram at once gave the means of measuring the melting point of a pure metal.

DISCUSSION.

Sub-Carbide Theory.

Mr. V. C. Faulkner (hon. secretary), after thanking Mr. Patchin for the way in which he had put the facts before the meeting, said that he himself was brought up in a sub-carbide school. A thing he had never been able to understand from this point of view was as to whether it was still considered that γ iron was hard, because if so, he would like to be shown a sample of pure iron hard. That could not be done without adding carbon. Reasoning in a similar manner, he asked Mr. Patchin if he could give any other instance in chemistry where they could retain the allotropic modification upon the addition of impurity. Personally, for teaching moulders and hardeners he found the sub-carbide theory very much handier than the allotropic theory, because the latter was too involved. With regard to the slides of metals containing manganese sulphide, why was it that there was always a white area around it?

Mr. Patchin said there was not always.

Mr. Faulkner replied that there was usually. Also, he said, that it would have been interesting if Mr. Patchin had referred to strengths of the metals when interpreting the diagrams.

Mr. Patchin said he was not aware that he had before him an expert who had been trained in sub-carbide theories, but really his work was concerned with that end of the diagram in which he did not think the sub-carbide theory entered. He agreed, of course, that foundrymen would be interested in strengths perhaps more than in the interpretation of the diagrams, but the subject he had to deal with was not the strength of cast iron or steel, but the interpretation of diagrams and of micro-structure.

At this point Mr. Patchin was compelled to leave, but the discussion was continued.

Allotropy of Iron.

The Branch-President, enlarging upon that part of Mr. Patchin's remarks with regard to the allotropic forms of iron, made it clear that there were not really three sorts of iron. There was only one element iron; if they took a magnet and tried to lift a piece of iron it would be found possible, but if the iron were gradually heated a temperature would be reached at which the magnet would no longer lift the iron. Therefore, in order to differentiate between the condition of an iron when it could be lifted by a magnet and when it could not, it had to be given another name, but it could not be said that it was not the same iron. When the iron was heated still further something else happened, namely, that the electrical conductivity of the iron was not the same in proportion as it was when the iron passed from the cold temperature to that at which it was no longer magnetic, and higher and again they had to give a name to differentiate between the condition of the iron before and after the change of electrical conductivity. He did not want the members to think that there were three different irons, but merely three different conditions of physical properties, and in putting down a diagram it was essential to show those points if they were going to be honest. Those points were used scientifically, because it so happened that the temperature at which a piece of steel was no longer magnetic was very often the temperature at which the steel could be hardened very successfully. Mr. Faulkner had mentioned the white areas surrounding the manganese sulphide patches, and the phosphide eutectics. That was quite true. If one examined a piece of steel with ghost lines, *i.e.*, segregations of manganese sulphide and phosphide eutectic, one nearly always found a sort of white envelope around them. That was very largely due to the fact that in the cooling out of iron the manganese sulphide patches and phosphide eutectic patches cooled at a lower temperature than the others, *i.e.*, they remained liquid, and seemed to cause the carbon in some instances to be dissipated from those areas, but in other instances, if the carbon were sufficiently high, they caused the carbon to remain round them; in some cases there was ferrite round them and sometimes cementite. He would not go into the sub-carbide theory.

Mr. Faulkner asked whether γ iron was supposed to be hard.

Is Gamma Iron Hard?

The Branch-President said that personally he did not think that any pure iron α, β or γ iron, *i.e.*, elementary iron, could be hardened. So far as γ iron was concerned, he did not believe it was hard. One of the great difficulties was that one could not examine alloys when they were in the liquid condition with the same facility as when they were at normal temperatures. Continuing, he said that Mr. Patchin did not, perhaps, enlarge so much as he might have done on the significance on the diagrams of the lines that he had drawn. The diagrams represented what happened when alloys cooled down from the liquid to the normal temperature, and were in a state of equilibrium, but it was quite obvious that if they were to quench at some of those high temperatures certain happenings would be suppressed and the characteristics of the metal would be altered entirely. The diagrams had been drawn assuming always that the metal had been thoroughly annealed, and in many instances it meant annealing, not for an hour or two, but for many days.

Lead in Brass.

Mr. H. E. Hand said that Mr. Patchin had referred to a brass with 1 per cent. of lead which was insoluble. Professor Carpenter, however, had had a piece of brass containing 3 per cent. of lead, which was soluble, and he would like an explanation of that if possible.

The Branch-President replied that Professor Carpenter had demonstrated that he had not been able to detect free lead in an alloy of that composition, but the mere fact that he had not been able to detect free lead did not satisfy him that it was not in solid solution. It might be in such a fine state of solution that up to the present it could not be detected, but he was not able to say that it was actually in solid solution. Although they might feel certain that it did not make a solid solution, they could not detect it under the microscope in the present state of development. It must be remembered that, although the microscope might have been used for a considerable time for the examination of fractures, microstructure was a comparatively new science, and that was one reason why, in drawing diagrams, investigators sometimes put a dotted line, because their researches had led them to believe that the solid solution was not formed, and yet they were not able to detect the free metal.

A Melting Point Query.

Mr. E. H. Brown said that when a sample of iron solidified it solidified at a different temperature from that at which it melted on re-heating, and he would like an explanation of that.

The Branch-President asked whether Mr. Brown was speaking of iron or cast iron.

Mr. Brown said he referred to cast iron.

The Branch-President said the answer was that it was very difficult indeed in a complicated metal such as cast iron, a compound metal which, of course, contained quite a number of elements, accurately to determine either the freezing point or the melting point, because there were plastic ranges. The arrest points were not definite, as in the pure metal. If they took the freezing point of pure tin they found such a very decided and distinct arrest point that there was no question about it, and the melting temperature would coincide with the freezing point, but it was very difficult to determine the freezing point or melting point of a complicated metal such as cast iron. Unless one had carried out a freezing point determination one was not really in a position to

appreciate all that had been said that evening. Once one started on that sort of work one became fascinated, and he suggested that members should melt a quantity of tin in a crucible, take the temperature every half minute with an ordinary glass thermometer, and observe the freezing point for themselves. He believed they would then wish to continue with lead and other metals. He strongly advised them to do that in their spare time, and they would find that many of their difficulties in connection with cooling curves and diagrams would disappear very quickly, because they were enabled to visualise what was happening better than if they had not attempted it. Another point that had been raised by Mr. Faulkner was the effect of graphite flakes on the tensile strength of specimens, *i.e.*, that if there were a graphite flake running across the active length of the specimen it would be a plane of weakness, and would have a greater influence than a flake of graphite running longitudinally with the active length of the specimen. If there were a fairly large flake of graphite right up on the circumference of the active length of the test bar it would open out, just in the same way that a piece of cloth, if nicked with a pair of scissors, could be torn across, and probably the specimen would break in the test machine at a rather low stress.

Mr. H. O. Slater (Past Branch-President) said the only fault he had had to find with the lecture was that it was not long enough, and it would be valuable to have a series of lectures from Mr. Patchin. The lecturer had cleared from his (Mr. Slater's) mind many little difficulties, and had made many points very much clearer to him.

Mr. Gibb said that Mr. Patchin had done the London Branch a very great service if he had only proved to the members the need for technical education, and he hoped that the Council would press forward a programme with regard to the education of apprentices.

The Branch-President, replying to Mr. Slater, said that it would be extremely interesting if Mr. Patchin could be persuaded to give a similar address on just that portion of the iron-carbon diagram that included the foundry iron, in order to give some idea as to why it was that such varying results were obtained in the foundry, so far as tests were concerned, from the same iron. So much depended on the rapidity with which the iron cooled in the mould and the initial temperature. That portion of Mr. Patchin's diagrams which represented the steels, and which looked fairly simple, had been the subject of no less than ten separate addresses to men who were supposed to know something about it, and if ten separate lectures could be given to metallurgists on that portion of the diagram, it could be understood what a difficulty Mr. Patchin must have had in compressing all that he had had to say in the way he had done.

Meeting Times Discussed.

A suggestion was then made by Mr. M. N. Abaza (Engineer to Messrs. Vickers, Ipswich) that the meetings of the London Branch should be held at week-ends, for the convenience of members living some distance from London. This suggestion was supported by Mr. Faulkner, who pointed out that the most successful meetings of the Institution that he had known were held in Manchester at 4 p.m. on Saturdays, and at Newcastle-on-Tyne at 6 p.m. on Saturdays. Mr. Hall and Mr. E. H. Brown also supported, the latter, who had come from the Newcastle Branch, confirming Mr. Faulkner's remarks, and pointing out that the members of that branch were as scattered as were the members of the London Branch.

The Branch President said that the matter had already been before the Council of the London Branch on several occasions, and he would bring it up for consideration again. Members were asked to indicate by a show of hands, for the information of the Council, whether they would prefer that the meetings of the Branch should be held on Thursday evenings, as at present, on Friday evenings or on Saturday afternoons, and the majority favoured the latter. Probably, said the Branch President, the Council would circularise the whole of the members, putting forward propositions with regard to the times of meetings.

This concluded the proceedings.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Electric Resistance Furnaces.

To the Editor of The Foundry Trade Journal.

Sir,—An account of a lecture before the Royal Society of Arts on February 7 appeared in your issue of March 15, and on reading this we were interested to note that the chairman, Sir Robert Hadfield, had made special mention of an occasion when he saw electrolytic iron melted and poured from an electric crucible furnace of the resistance type with an inappreciable absorption of carbon.

We wish to point out that we are the manufacturers of this furnace, and not the American Crucible Company, as incorrectly reported.—Yours faithfully,

A. R. Bosman, Director.
For The Morgan Crucible Company, Limited,
Battersea Works, London, S.W.11.
March 24.

Price of Belgian Foundry Coke.

The Commercial Secretary at Brussels (Mr. J. Picton Bagge) has forwarded to the Department of Overseas Trade an extract from the "Echo de la Bourse" of March 15, which states that the new price of coke has been difficult to fix owing to the great cost of coking coal. The following solution has finally been reached:—

From now on there will be two different categories of coke:—(A) Entirely made from Belgian coal, and (B) that made from a mixture of Belgian, English, and, later on, German coal.

The price of (A) coke has been fixed at 160 francs from March 15 to April 15. The price of (B) coke will be obtained by multiplying the cost of coking coal by 1.4.

The equal distribution of these two basic prices (in proportion to output) will give the average price to be applied to the whole of Belgium.

It is difficult to say what the price will be, owing to the fluctuations of the rate of exchange, but it will probably be between 190 and 200 francs per ton.

The price of German coke has been fixed at 160.50 francs per ton (in anticipation of deliveries from the Ruhr).

Gazette.

Messrs. S. Hefford and W. J. Shepherd, malleable ironfounders, New Street, West Bromwich, trading under the style of the New Malleable Foundry Company, have dissolved partnership.

The shareholders of the Monmore Green Rolling Mills Company, Limited, have decided to wind up the company. Mr. J. E. Jordan, 79, Lichfield Street, Wolverhampton, has been appointed liquidator.

The shareholders of the Dock Engineering Company, Limited, have decided to wind-up the company, for which purpose Mr. C. H. Longdon-Griffiths, 11, Merchants' Exchange, Cardiff, has been appointed liquidator.

At the expiration of three months, the names of the undermentioned companies will be struck off the Register of Joint Stock Companies, and the companies will be dissolved: Patrick Engineering Company, Limited; Pullan Engineering Company, Limited; Railway Supply, Construction & Engineering Company, Limited; Richard Rostron (Engineers), Limited; Saxon Engineering Company, Limited; Swindon Engineering Works, Limited; Universal Engineering Company, Limited; and the Wellington Steel Works Company, Limited.

From "Punch."

A sign of the approaching times is an advertisement in an engineering journal for a first-class moulder in a hot-cross bun factory.

An Italian Sample Fair is to be held in Milan from April 12 to 27, 1923. The Italian Chamber of Commerce in London, 4, Queen Street Place, E.C.4, are in a position to supply any commercial or industrial information concerning the Fair and respecting trade with Italy in general.

IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Business in the Cleveland iron market of late has become more and more limited in scope, by reason of the extreme difficulty in securing supplies, while inquiries are still coming to hand, though in somewhat decreased volume, a not unusual happening previous to the first holiday in the year. With smelters already fully sold, and only with some difficulty fulfilling current contracts, it is now next to impossible to secure prompt deliveries beyond retail quantities, for which consumers have practically to depend upon merchants, on the latter's own terms. So far, it is understood no decision has been reached by makers to increase the output of Cleveland foundry pig, an insurmountable obstacle being the question of coke supplies, which are extremely difficult to obtain even at the exorbitant prices now ruling. Meanwhile, the export trade from Tees-side is well maintained, shipments of pig-iron from the Port of Middlesbrough during March, up to and including the 20th inst., having amounted to 22,307 tons, as compared with 18,645 tons in the corresponding period of February. Cleveland pig-iron prices are practically unchanged, any No. 1 obtainable realising as much as 132s. 6d., and No. 3 G.M.B. is extremely firm at 127s. 6d., with No. 4 foundry stronger at 125s. No. 4 forge is unobtainable and quite nominal at about 122s. 6d. per ton.

MANCHESTER.—Current demand for foundry iron in this district continues restricted, local consumers being reluctant to deal at the prices quoted, although the figures now in force for Midland makes compare favourably with the inflated values of Cleveland qualities. This is evidenced by the fact that orders for No. 3 foundry iron come to the Derbyshire furnaces from Middlesbrough, and Tees-side consumers will pay a higher price at the Derbyshire furnaces than the makers even try for when they offer to the Lancashire consumers. There is even a demand growing up amongst Scottish founders for Derbyshire iron, although this iron, when delivered in Scotland, will cost more than No. 3 Scotch pig. The present quotation for No. 3 pig-iron in Manchester is now 115s. per ton, with some sellers asking 117s. 6d., but ironfounders are not paying this price yet; or, if so, only for small quantities urgently wanted. Scotch No. 3 iron is now quoted in Manchester at £7 per ton, and hematite from the East Coast at about the same figure.

THE MIDLANDS.—In this area similar conditions of scarcity and high prices of pig-iron are found, and new business is practically non-existent. Any iron that comes on to the market commands the full quotation, sellers being completely masters of the situation. For the time being forward buying is completely at a standstill. Consumers are hesitating to cover on the high quotations which their inquiries bring out, but even if this were not so there would still be much the same difficulty, because smelters are just as much afraid to commit themselves deeply. Altogether it is a very unsatisfactory situation, and the way out is not yet opened.

SCOTLAND.—Consumers in the North are also experiencing severely restricted supplies of pig, the high prices now quoted being a further factor in restraining buyers on forward account. The Falkirk founders are buying very little pig-iron, and practically none of it is Middlesbrough, but this is hardly a matter of surprise. On the basis of 127s. 6d. f.o.b. Tees, No. 3 Middlesbrough at Falkirk is £6 16s., as compared with No. 3 Scotch at £6 3s. 6d. and Midland at £6 2s. 6d. There is no Continental iron on offer.

Finished Iron.

Steady activity continues in evidence in most branches of the trade in finished material, the advance in the price of marked bars recently announced having had little effect upon the market, having been regarded as very moderate in existing conditions. Crown bars also at £12 10s. for the better qualities may be considered at a reasonable figure when taking into consideration the high costs of production now prevailing, and it will not be in the least surprising should a further advance be shortly announced. Commoner bars are firm on the basis of £11 10s. for nut and bolt qualities. The bar trade, as a whole, however, is much less satisfactory than it was at the turn of the year. For one thing, it is very difficult to quote a forward price owing to the uncertainty about pig-iron, and the amount of "cover" which the seller would require to protect himself against possible developments would make the price rather unattractive to the buyer. Gas strip continues to experience the benefit of the reduction of indirect foreign competition.

Scrap.

The growing stringency of supplies of new materials is now diverting the attention of consumers more and more in the direction of scrap material, for which there is now an increasing demand. Inquiries from Scotch foundries continue to pour in to sellers, but owing to the depletion of stocks the parcels which can be offered are small. Heavy machinery and scrap railway chair run about 105s. to 107s. 6d., and ordinary cast 100s. Light metal and furnace fire-bars have gone up in price considerably, and can now be sold at 82s. 6d. to 85s. In Yorkshire the demand for most classes of scrap continues keen, but consumers are buying little, if any, of the material on offer from Germany. The prices asked for this are tempting compared with those quoted by sellers here, but the quality is said to be indifferent, making the risk of charging a furnace with scrap of doubtful carbon content too great to be undertaken. The famine in all classes of steel scrap is becoming very pronounced, and prices have again stiffened. Builders' light cast-iron scrap has gone up to 90s. per ton, cast-iron lump for basic furnaces is 92s. 6d., heavy wrought-iron scrap new costs 105s., and machinery cast-iron scrap for foundry is 110s., all delivered West Riding stations.

Steel.

The volume of inquiries both on home and overseas account in this market continues satisfactory, and every week more labour is being absorbed in the various branches, of which, perhaps, that applying to semi-products is for the time being most active. In South Wales at the moment the bulk of demand is for soft steel billets, for which makers are fully booked up for some time to come, and in consequence are declining acceptance of further forward commitments. In this district, also, some good orders for rails are in hand, and this branch should benefit by the large contracts now known to be pending for some of the principal railways. In South Staffordshire there does not appear to have been an official alteration in the basis for sections, but some makers are quoting 5s. higher, and, it is reported, are not experiencing any difficulty in securing business. In the market for alloys the situation in ferro-manganese is unchanged, and with the shortage in coke supply production is retarded.

Metals.

Copper.—Although somewhat irregular in tendency, the market for standard copper has been firm on the whole, prices for both positions disclosing a slight advance. Reports from the States indicate a very strong position in that country, and prices have again been advanced. Home consumers are buying on a moderate scale, having apparently covered their requirements for the near future. The position is so strong, however, that the variations in the demand over here appear scarcely to affect the market, and it is likely that firm quotations will prevail for some time to come.

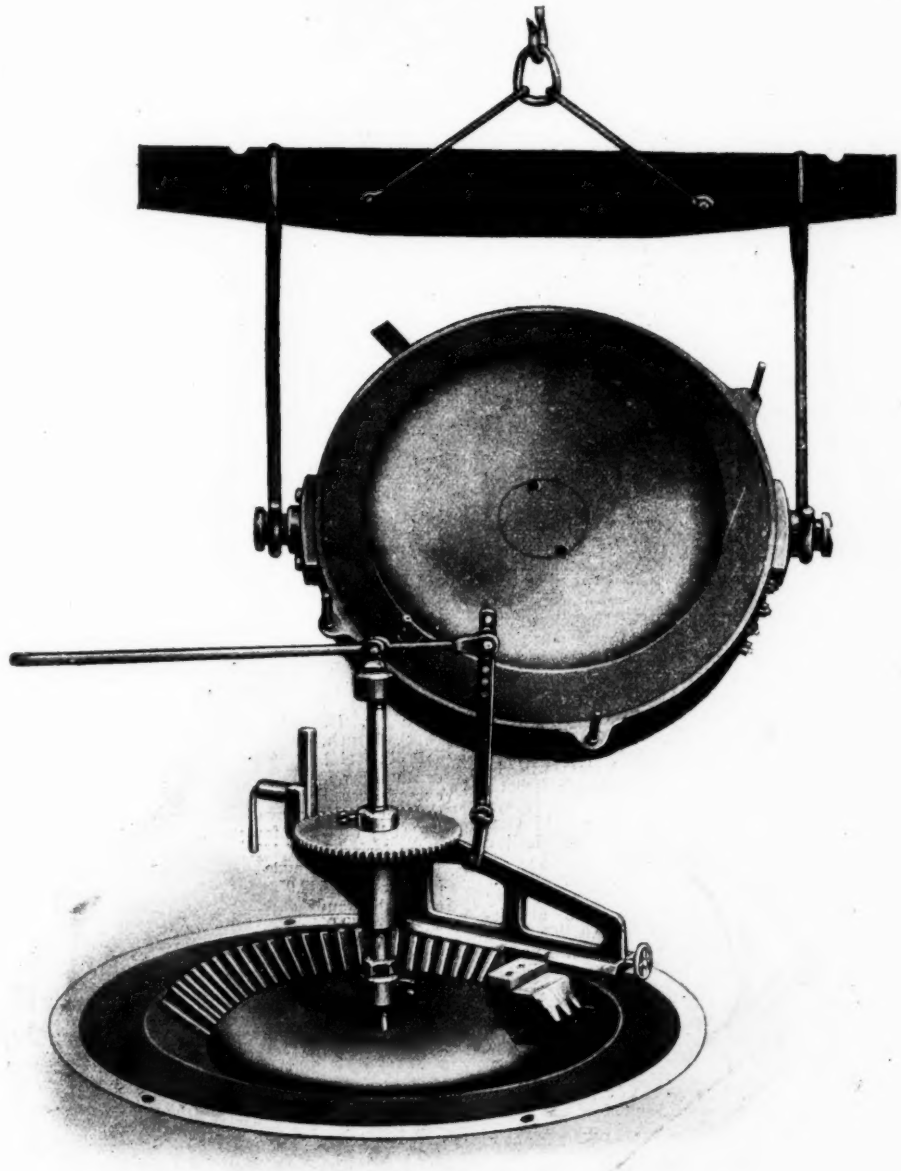
Tin.—Movements in standard tin have continued on an active scale during the past week, the chief feature having been the comparative scarcity of near metal, resulting in a temporary disappearance of the contango, later widening out on some heavy purchases on forward account. This has been expressed in a substantial demand for late April dates, which at times commanded a premium of 10s. per ton over three months. Consumption is good, especially in America, and the statistical position at the end of the month is expected to make a favourable showing. Exports of tin from the Federated Malay States during the month of February are officially given as 3,020 tons. This compares with 3,188 tons in January last and 2,572 tons in the corresponding month of last year. Exports for the first two months of the current year amounted to 6,208 tons, against 5,715 tons for the same period of 1922.

Spelter.—Conditions in this metal have been active and firm, with buying strong for May/June delivery. Messrs. Rudolf Wolff & Company report that much of the firmness is a reflection of the strength of the market in America, where prices have advanced under the influence of an excellent consumption, statistics there for February showing deliveries to have exceeded production by 5,700 tons. February output, 42,443 tons; February deliveries, 48,143 tons.

Lead.—Movements in the market for soft foreign pig have revealed a somewhat weaker tendency during the week, heavy arrivals from South American ports contributing to this result as far as prompt metal is concerned, without much effect upon forward dealings.

The "VULCANIA" PATENT WHEEL MOULDING MACHINE.

Patent No. 5049.



THE "VULCANIA" PATENT WHEEL MOULDING MACHINE is for moulding spur wheels with straight, sloping or Vee-shaped teeth, also bevel wheels, skew gear wheels, worm wheels and internal wheels. The machine head is carried on a pillar which is held in a base-plate bedded in the floor sand, and is made to slide on the pillar by means of a lever and link carried on a joint bearing, or by rack and pinion, or screw if thought advisable for the particular work it is being used for.

An adjustable stop collar is provided for accurately deciding the depth of mould. On the removable head a slide is carried for supporting the patterns of the teeth to be moulded. This slide is made adjustable by screw or pinion gearing to the diameter required. The number of teeth to be moulded is decided by a special dividing plate into which a steel wedge or finger engages. The special dividing plate has milled vees, at the angle of 60° inclusive, around its circumference, to receive the steel wedge, which is adjusted by a screw having an internal spring to keep it in tension and to lock the head when ramming operations are being carried out.

JAMES EVANS & CO., BRITANNIA WORKS (MANCHESTER), LIMITED.

BLACKFRIARS, MANCHESTER.

Trade Talk.

The British Griffin Chilled Iron & Steel Company, Limited, Barrow, have closed down their works after running for the past 22 years.

It is stated that the United Steel Companies, Limited, will light another furnace at their Moss Bay works at Workington before the end of the month.

Sir W. G. Armstrong, Whitworth & Company, Limited, have removed their hydro-electric department from 8, Great George Street, to 51, Victoria Street, London, S.W.

Wilbraham & Smith, tinplate, iron and steel merchants, 8, Laurence Pountney Hill, Cannon Street, London, E.C.4, have removed to 107, Upper Thames Street, London, E.C.4.

The Consolidated Pneumatic Tool Company, Limited, of Egyptian House, 170, Piccadilly, London, W.1, have been appointed sole selling agents for Weldrics and Weldrines patented electrodes.

Mr. N. C. Laing, 2, Blue Boar Court, Manchester, has been appointed agent for W. & J. Lawley, Limited, brass and ironfounders, of Britannia Foundry, West Bromwich, in succession to Mr. T. M. Eatham.

The Australian Ore & Metal Company Pty., Limited, the Electrolytic Zinc Company of Australasia, Limited, and the Zinc Producers' Association Pty., Limited, are removing to 27, Old Broad Street, London, E.C.2.

Licences under the Non-Ferrous Metal Industry Act, 1918, have been granted to the Australian Ore & Metal Company Proprietary, Limited, Pinners Hall, Austin Friars, London, E.C.2; and E. Aylwin & Company, 86, Leadenhall Street, London, E.C.3.

Christmas, Hulbert & Walters, Limited, steelworks' engineers and contractors, of Caxton House, Westminster, have obtained the permission of the Board of Trade to shorten their title to Christmas & Walters, Limited, under which they will in future be known.

At a meeting of the West of Scotland Iron and Steel Institute, held on March 16, in the Royal Technical College, Glasgow—Mr. E. H. Lewis, president, in the chair—Mr. A. W. Macaulay read a paper on "Some Developments in Ball and Roller Bearing Work, with Particular Reference to Steel Rolling Mill Plant."

The council of the South Wales Institute of Engineers announce that two Lewis prizes will be open for competition by members, associate members, associates, and students for a paper upon the following subject, viz.: "Modern Developments in Coal Conveyors and Haulage Arrangements for dealing with the Coal from the Working-face to the Pit Bottom."

The Women's Engineering Society, of which Lady Parsons is president, is to hold a conference at Birmingham University from April 11 to 14. The programme includes visits to various works, and papers on engineering subjects. The conference will be attended by delegates from overseas, among them Mrs. L. M. Gilbreth, representing the American Society of Mechanical Engineers.

A new vein of copper has been discovered by Mr. John Pritchard, Pen Lon, Llaneilian, Amlwch, Anglesey, which is claimed to be one of the most promising of recent finds. The spot lies about two miles from the celebrated Parys Mountain mines, and the new find is held to be a continuation of that vein. The spot where the discovery was made, and where mining operations can, it is believed, be carried on, is on the Anglesey coast.

Company News.

Crossley & Davenport, Limited, Yorkshire Foundry, Black Bull Street, Leeds. Capital £40,000 in £1 shares. Iron merchants.

Thomas Furnival, Limited.—Capital £1,000. Metal merchants and refiners, smelters, etc. Solicitor: W. H. Draper, 14, Cook Street, Liverpool.

Jones & Weatherley, Limited.—Capital £1,000. Iron founders, mechanical engineers, etc. Solicitor: M. H. Bailey, 40A, Temple Street, Birmingham.

W. Shaw & Company, Limited, Wellington Foundry, Middlesbrough.—Capital £80,000 in £1 shares. Ironfounders. Directors: W. Shaw and H. A. Shaw.

King & Son (Harlesden), Limited.—Capital £200. Iron, steel and metal merchants, etc. Secretary: C. F. J. King, 43, Acton Lane, Harlesden, Middlesex.

Sir W. G. Armstrong, Whitworth & Company, Limited.—Ordinary dividend for half-year ended December 31, 6d. per share, making 1s. per share for year, less tax.

Coltness Iron Company, Limited.—Interim dividends on first and second preference shares declared; announcement on ordinary dividend postponed until end of financial year.

Willetts Brothers (Old Hill), Limited, Lawrence Lane, Old Hill.—Capital £6,000 in £1 shares, to acquire the business of ironmasters and founders, galvanisers, etc., carried on by S. Willetts, sen., and G. Willetts, sen., as Willetts Brothers.

Crystal Engineering Company, Limited, 1, Adelaide Road, London, N.W.3.—Capital £5,000. Directors: H. G. Mountain (managing and permanent), D. S. D. Nicsoll, and F. A. L. Sloot.

Phoenix (Kidderminster), Limited, Callows Lane, Mill Street, Kidderminster.—Capital £1,000 in £1 shares. General engineers. Directors: A. J. Badger, R. S. Beddoes, and H. Ballard.

Robey & Company, Limited.—Profit, £26,246; depreciation, £10,239; brought forward, £34,969; available, £35,203; dividend, 2½ per cent., less tax, on both preference and ordinary shares; carry forward, £26,751.

Davies, Jones & Clench, Limited.—Capital £3,000 in 2,000 preference shares of £1 and 4,000 ordinary shares of 5s. each. Mechanical and general engineers. Directors: W. H. T. Jones, High Street, Raglan, and G. C. Clench, Castle Parade, Garage, Usk.

Delta Metal Company, Limited.—Drawn from special contingency fund, £20,000; sum of £4,318, representing excess over liabilities, transferred to profit and loss account; balance available, £10,856; brought forward, £10,094; dividend for year, 7½ per cent., free of tax; carry forward, £7,450.

Stewarts & Lloyds, Limited.—Depreciation, £70,000; net profit, £522,078; brought forward, £185,817; interim dividends on preference and preferred ordinary shares, £59,000; reserve, £100,000; employés' benefit fund, £10,000; dividend, 6 per cent. per annum for half-year on preference, £16,500; dividend, 10 per cent. per annum for half-year on preferred ordinary, £42,500; dividend, 2s. per share, free of tax, on ordinary shares, £263,810; bonus, 6d. per share, free of tax, on ordinary, £65,952; carried forward, £150,132.

Sir John Cowan has been elected a director of Bolckow, Vaughan & Company, Limited.

Messrs. Wailes Dove Bitumastic, Limited, manufacturers of "Bitumastic" solutions, have opened a branch office at 2, Bank Street, Sheffield, which will be in charge of Mr. Arthur Swindale.

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,
FIRE CLAY.
Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.
STEEL MOULDERS' COMPOSITION, SILICA CEMENT.
J. GRAYSON LOWOOD & Co., Ltd.,
DEEPCAR, nr. SHEFFIELD.
Telegrams: "LOWOOD, DEEPCAR."

JOHN HALL & CO.,
OF STOURBRIDGE, LIMITED,
STOURBRIDGE, ENGLAND.

Manufacturers of
FIRE BRICKS, BLAST FURNACE BRICKS & CUPOLA BRICKS.

NOTHING IN THE TOMB OF TUTANKHAMEN
can have been more carefully prepared for its purpose than is the Steel Foundry Sand
"YORKSHIRE SAND"
FOR ITS PURPOSE.
☞ CHEAPNESS OF FIRST COST IS NOTHING — MARGARINE IS CHEAPER THAN BUTTER.
☞ WASTERS AND FETTLING COSTS ARE DEAR.
General Refractories Co. Ltd.
SHEFFIELD.
MANAGING DIRECTOR - - FRANK RUSSELL, F.G.S., F.E.S.
PHONE: 3577 (2 LINES). TELEGRAMS: "REFRACTORY, SHEFFIELD."

SIEMENS' STEEL PROCESS
BOILER, SHIP and BRIDGE PLATES, etc. ANGLES and all forms of Sectional Bars. TYRES and AXLES to all requirements. CASTINGS of all kinds and of Largest Sizes. FORGINGS of every description. BILLETS, BLOOMS, RAILS.
SPECIAL STEEL FOR CONSTRUCTIVE PURPOSES.
The STEEL COMPANY OF SCOTLAND, Ltd.
Head Office: 23, ROYAL EXCHANGE SQUARE, GLASGOW.
Works: HALLSIDE, NEWTON and BLOCHAIRN, GLASGOW.
CONTRACTORS TO HOME, COLONIAL AND FOREIGN GOVERNMENTS.
Established 1872. *Telegraphic Address: "Steel, Glasgow."*

TELEGRAMS: "IRON BILSTON."
West Midland Refining Co.,
Bilston.
COLD BLAST IRONS
for Chilled Castings.
Chills and analysis guaranteed.
CHARCOAL
REFINED · HEMATITES
for Malleable Castings.

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	73	5	0
Three months	74	2	6
Electrolytic	81	10	0
Tough	76	10	0
Best selected	76	10	0
Sheets	106	0	0
India	93	0	0
Wire bars	82	0	0
Do. Apr.	82	0	0
Do. May	82	0	0
Ingot bars	82	0	0
H.C. wire rods	86	10	0
Off. aver., cash, Feb.	67	15	3
Do. 3 mths., Feb.	68	9	6
Do. Settlement Feb.	67	15	1½
Do. Electro, Feb.	74	15	4½
Do. B.S., Feb.	72	6	3
Aver. spot price, copper, Feb.	67	14	3
Do. Electro, Feb.	75	0	9
Solid drawn tubes		14¾d.	
Brazed tubes		14¾d.	
Wire		11½d.	
Yellow metal rods		7½d.	
Do. 4x4 Squares		9d.	
Do. 4x3 Sheets		10d.	

BRASS.

Solid drawn tubes	13d.
Brazed tubes	14¼d.
Rods, drawn	11½d.
Rods, extruded or rolled	7½d.
Sheets to 10 w.g.	11d.
Wire	11d.
Rolled metal	10½d.

TIN.

	£	s.	d.
Standard cash	213	0	0
Three months	214	5	0
English	213	0	0
Bars	215	0	0
Chinese	212	5	0
Straits	220	15	0
Australian	216	15	0
Eastern	231	0	0
Banca	216	0	0
Off. aver., cash, Feb.	190	12	0¾
Do. 3 mths., Feb.	192	7	5½
Do. Sttlment, Feb.	190	11	4½
Aver., spot, Feb.	190	10	4½

SPELTER.

	£	s.	d.
Ordinary	35	5	0
Remelted	33	10	0
Hard	29	0	0
Electro 99.9	43	5	0
English	36	0	0
India	31	0	0
Prime Western	36	0	0
Zinc dust	50	0	0
Zinc ashes	14	0	0
Off. aver., Feb.	35	8	9
Aver., spot, Feb.	35	12	2½

LEAD.

	£	s.	d.
Soft foreign ppt	27	17	6
English	29	0	0
Off. average, Feb.	28	6	5½
Average, spot, Feb. 28	10		4½

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	43	0	0
Do. V.M. ex whf.	43	0	0
Dutch	42	0	0
Rods	50	0	0
Boiler plates	41	0	0
Battery plates	42	0	0

ANTIMONY.

	£	s.	d.
English regulus	30	10	0
Special brands	36	10	0
Chinese	27	10	0
Crude	20	0	0

QUICKSILVER.

Quicksilver, nominal 12 2 6

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro-silicon—	
45/50%	£12 7 6
75%	£20 5 0
Ferro-vanadium—	
35/40%	17/- lb. va.
Ferro-molybdenum—	
70/75% c. free	9/6 lb. mo
Ferro-titanium—	
23/25%, carbonless	1/1 lb.
Ferro-phosphorus, 20/23%,	£26
Ferro-tungsten—	
80/85%, carbon free	1/5 lb.
Tungsten metal powder—	
98/99%	1/10½ lb.
Ferro-chrome—	
4/6% car.	£23 0
6/8% car.	£22 0
8/10% car.	£21 10
Ferro-chrome—	
Max. 2% car.	£52 0
Max. 1% car.	£62 0
Max. 0.70% car.	£72 0
67/70%, carbonless	1/6½ lb.
Nickel—99%, cubes or pellets	£130 0
Cobalt metal—98/99%	12/- lb.
Aluminium—98/99%	£105
Metallic Chromium—	
96/98%	4/6 lb.
Ferro-manganese (net)—	
76/80%, loose	£16
76/80%, packed	£17
76/80%, export	£16
Metallic manganese—	
94/96%, carbonless	2/- lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	s. d. 2 6
Finished bars, 18% tungsten	3 0

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares 3 in. to 8 in. inclusive 4d. lb.

Rounds and squares under ½ in. to ¼ in. 3d. lb.

Flats under 1 in. by ¾ in. to ½ in. by ¼ in., and all sizes over four times in width over thickness 3d. lb.

Bevels of approved sizes and sections.. 6d. lb.

If in coils.. 3d.lb.

Bars cut to length 10% extra

Scrap from high-speed tool steel—

Scrap pieces	3d.
Turnings and swarf	1d.

Per lb. net, d/d steel makers' works.

SCRAP.

	£	s.	d.	£	s.	d.
South Wales—						
Heavy steel	5	0	0	5	10	0
Bundled steel & shrngs.	4	5	0	5	0	0
Mixed iron & steel	4	5	0	4	10	0
Heavy cast iron	4	2	6	4	7	6
Good machinery for foundries	4	5	0	4	10	0
Cleveland—						
Heavy steel				4	12	6
Steel turnings				3	7	6
Cast-iron borings				3	7	6
Heavy forge				5	5	0
Bushelled scrap				4	12	6
Cast-iron scrap				5	2	6
Lancashire—						
Cast-iron scrap				5	0	0
Heavy wrought				5	0	0
Steel turnings				3	12	6

London — Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	70	0	0
Brass (clean)	41	0	0
Lead (less usual draft)	26	0	0
Tea lead	24	0	0
Zinc	26	0	0
New aluminium cuttings	67	0	0
Braziery copper	59	0	0
Gun metal	53	0	0
Hollow pewter	180	0	0
Shaped black pewter	100	0	0

PIG-IRON.

N. E. Coast—	
Foundry No. 1	132/6
Foundry No. 3	127/6
Forge No. 4	122/6
Mottled	—
Hematite No. 1	126/-
Hematite M/Nos.	125/-
Midlands—	
Staffs. common	—
,, part-mine forge	—
,, ,, foundry	—
,, Cold blast, ord.	190/-
,, ,, roll iron	200/-
,, basic	—
Northants forge	95/-
,, foundry No. 3	105/-
,, basic	105/-
Derbyshire forge	97/6
,, foundry No. 3	120/-
,, basic	115/-
Scotland—	
Foundry No. 1	125/-
,, No. 3	120/-
Hematite M/Nos.	130/-
Sheffield (d/d district)—	
Derby forge	101/-
,, foundry No. 3	123/6
Lincs. forge	100/-
,, foundry No. 3	105/-
,, basic	120/-
E.C. hematite	135/3
W.C. hematite	136/3

All d/d in the district.

Lancashire (d/d eq. Man.) —	
Derby forge	—
,, foundry No. 3	130/-
Northants foundry No. 3	—
Cleveland foundry No. 3	—
Staffs. foundry No. 3	—
Lincs. forge	—
,, foundry No. 3	—
Dalzell, No. 3	137/-
Summerlee, No. 3	137/-
Glengarnock, No. 3	137/-
Gartsherrie, No. 3	137/-
Monkland, No. 3	137/-

FINISHED IRON & STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£	s.	d.
Bars (cr.) £12 to	12	10	0
Angles	12	5	0
Tees to 3 united ins.	12	10	0
Nut and bolt	11	10	0
Hoops	15	0	0
Marked bars (Staffs.)	14	0	0
Gas strip £12/5 to	12	10	0
Bolts and nuts, ¾ in. × 4 in.	20	10	0
Steel—			
Ship plates	10	10	0
Boiler plates	14	0	0
Chequer plates	11	5	0
Angles	10	0	0
Tees	11	0	0
Channels	10	10	0
Joists	10	0	0
Rounds & squares 3 in. to 5½ in.	11	5	0
Rounds under 3 in. to ¾ in.	11	0	0
Flats, over 5 in. wide and up	11	10	0
Flats, 5 in. to 1½ in.	10	15	0
Rails, heavy	10	10	0
Fishplates	14	10	0
Hoops (Staffs.)	13	0	0
Black sheets, 24 g.	13	12	6
Galv. cor. sheets, 24 g. £19 5 0 to	19	10	0
Galv. fencing wire. 8 g. plain	18	5	0
Rivets, ¾ in. dia.	14	15	0
Billets, soft	10	0	0
Billets, hard	10	15	0
Sheet bars	10	0	0
Tin bars	8	16	0

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	1 4
Sheet	1 4¾
Wire	1 5¼
Rods	1 3½
Tubes	1 7
Castings	1 2

Delivery 3 cwt. free to any town.

10% phosphor copper, £40 above price of B.S.

15% phosphor copper, £50 above price of B.S.

Phosphor tin (5%), £30 above price of English ingots.

Charles Clifford & Son, Limited, Birmingham.

NICKEL SILVER, SHEET METAL, WIRE AND TUBES.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3¼ to 1/9½
To 15 in. wide	1/4 to 1/10
To 18 in. wide	1/4¾ to 1/10¾
To 21 in. wide	1/5½ to 1/11½
To 25 in. wide	1/6¼ to 2/0¼
Ingots for spoons and forks	9d. to 1/3
Ingots rolled to spoon size	1/- to 1/6
Wire round—	
3/0 to 10 G.	1/6½ to 2/1½

with extras according to gauge

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.	Dols.
No. 2X foundry, Phila.	31.76
No. 2 foundry, Valley	30.00
No. 2 foundry, Birm.	27.00
Basic	31.77
Bessemer	31.77
Malleable	31.77
Grey forge	31.27
Ferro-manganese 80% delivered	120.00
Bess. rails, h'y, at mill	43.00
O.-h. rails, h'y, at mill	43.00
Bess. billets	45.00
O.-h. billets	45.00
Wire rods	50.00
	Cents.
Iron bars, Phila.	2.72
Steel bars	2.35
Tank plates	2.35
Beams, etc.	2.35
Skelp, grooved steel	2.35
Skelp, sheared steel	2.35
Steel hoops	3.05
Sheets, black, No. 28	3.75
Sheets, galv., No. 28	4.85
Sheets, blue an'l'd, 9&10	2.90
Wire nails	2.80
Plain wire	2.65
Barbed wire, galv.	3.45
Tinplate, 100-lb. box	$4.95

COKE (at ovens).

Welsh foundry	40/- to 45/-
,, furnace	30/- to 35/-
Durham & North. fdy.	42/6
,, furnace	34/6
Other Districts, foundry	45/-
,, furnace	35/-

TINPLATES.

f.o.b. Bristol Channel ports.

I.C.Cokes,	20×14, box	24/6
,,	28×20, ,,	49/-
,,	20×10, ,,	32/10½
,,	18¾×14, ,,	23/3
C.W.	20×14, ,,	22/9
,,	28×20, ,,	46/6
,,	20×10, ,,	31/3
,,	18¾×14, ,,	23/3
Ternes, f.o.t.	28×20, ,,	45/-

TUBES.

	Up to and incl. 6 in.	
Gas ..	..57½%	Tube prices are now free.
Water	..52½%	
Steam	..47½%	

SWEDISH IRON.

Bars, hammered basis sizes—Basis price £22 to £23

	£ s. d.
Rolled Ordinary—Assortment ..	17 0 0
Nail Rods—	
Square, round and flats ..	17 10 0
Keg Steel	nom. £38 to £40
Faggot Steel	nom. £30 to £32
Blooms—	
Single welded ..	£10 to £11
Billets—	
Single and double welded	£13 to £14
Pig-iron—	
Grey, white or mottled	£6 15 to £7 5 0

Prices are without engagement. All quotations are f.o.b. Gothenburg, net cash against documents there.

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.		
Mar. 21	75	5	0	dec.	12/6
„ 22	74	17	6	„	7/6
„ 23	75	7	6	inc.	10/–
„ 26	73	15	0	dec.	32/6
„ 27	73	5	0	„	10/–

Electrolytic Copper.

Mar. 21	83	0	0	No change
„ 22	83	0	0	„
„ 23	83	0	0	„
„ 26	82	0	0	dec. 20/–
„ 27	81	10	0	„ 10/–

Standard Tin (cash).

Mar. 21	219	10	0	dec.	67/6
„ 22	223	15	0	inc.	85/–
„ 23	224	0	0	„	5/–
„ 26	216	15	0	dec.	145/–
„ 27	213	0	0	„	75/–

Tin (English ingots).

Mar. 21	220	0	0	dec.	60/–
„ 22	224	0	0	inc.	80/–
„ 23	224	0	0	No change	
„ 26	217	0	0	dec.	140/–
„ 27	213	0	0	„	80/–

Zinc Sheets (English).

Mar. 21	43	0	0	No change
„ 22	43	0	0	„
„ 23	43	0	0	„
„ 26	43	0	0	„
„ 27	43	0	0	„

Spelter (ordinary).

Mar. 21	36	17	6	dec.	10/–
„ 22	36	15	0	„	2/6
„ 23	36	10	0	„	5/–
„ 26	35	17	6	„	12/6
„ 27	35	5	0	„	12/6

Lead (English).

Mar. 21	30	0	0	No change
„ 22	29	15	0	dec. 5/–
„ 23	29	15	0	No change
„ 26	29	0	0	dec. 15/–
„ 27	29	0	0	No change

AVERAGE MONTHLY PRICES OF WEST COAST HEMATITE MIXED NUMBERS.

Year	Jan	Feb.	March	April	May	June	July.	August.	Sept.	Oct.	Nov	Dec.	Yearly Average.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1885	44 0	44 1	43 2	43 1	42 10	42 6	42 6	42 0	42 2	42 1	43 0	43 8	42 11½
1886	43 3½	42 0	42 0	41 6½	41 2½	40 0	40 0	41 2½	41 6	44 0	44 0	44 9	42 2½
1887	49 6	48 9½	45 6	43 2½	43 6½	44 1	44 0	44 2½	43 5½	41 6	41 9½	45 0	44 6½
1888	44 4	42 3	42 1½	42 0	41 2½	42 1½	42 6½	44 0	45 8½	44 6	44 6	45 3½	43 4
1889	44 4	45 2	47 3½	48 9½	48 6½	48 7½	50 1½	53 11	55 3	63 6	73 10	73 2	54 4½
1890	76 1½	65 1	63 3	55 1	53 9½	50 11	52 3½	56 4	58 0	58 2	57 5	54 4½	58 5
1891	52 9	50 10	48 11	47 9½	51 5	50 6	50 10	48 4	50 1	49 1½	48 3½	47 8	49 8½
1892	47 4	45 6	46 4½	47 8	49 5	50 4½	49 7½	49 10½	49 10½	48 8½	46 10	46 1½	48 2½
1893	46 0½	45 8	45 11	45 7	44 11	44 9½	44 10	45 3	45 0	44 6	44 7	45 8	45 3
1894	45 3	45 3	45 1½	45 1	43 11	43 11	43 9½	44 2	44 7½	43 7	43 5	43 3	44 3½
1895	42 8	42 5½	42 6	42 10	43 10	43 7½	44 10	45 11	49 11	48 9	47 7½	47 7½	45 2½
1896	47 0	48 9	48 9	48 2½	47 3	47 3	46 10	46 10	47 2	48 5	50 7	50 6	48 1½
1897	51 2	49 10	48 5	47 4	47 9½	48 6	47 0	47 3	47 3	47 0	48 3½	47 11	48 2
1898	48 9	48 10	49 4	49 8½	50 10	50 3½	51 0	52 5	53 11	55 8	57 3	56 10	52 1½
1899	59 1	59 9	57 7	59 6	64 7	70 10½	76 7½	72 2	74 3	75 0	78 1½	73 3	68 5
1900	75 3½	76 10	79 10	84 6	81 4	79 1½	83 4	81 5	79 11	76 10	77 8½	68 4	78 8
1901	60 2	59 0	57 9½	57 6½	57 8	57 4½	57 8	61 0	60 0½	59 9	58 7½	56 7	58 7½
1902	56 1	57 9½	59 3½	59 9	59 10½	60 0	60 0	60 8½	61 5	61 2	59 3	59 0	59 6
1903	58 5	58 8	61 1	59 5	57 10	57 3	56 7	56 3	55 9	54 8	52 4	52 4	56 8½
1904	52 8½	53 1	53 7	54 9	54 2	53 2½	52 9	52 5	52 2½	52 7	53 1	55 11½	53 5½
1905	57 9½	56 9	58 1	58 2	56 4	55 8	55 5½	56 7	61 0	68 9	69 9	70 11½	60 5½
1906	70 4½	65 2½	63 4½	63 9	64 5	64 6	64 1	66 2½	67 3	69 4½	72 4½	78 8½	67 5
1907	77 9	72 11	71 10	73 9	79 9½	76 9	77 9	78 4	75 11	72 9½	68 6	66 7	74 4
1908	62 7	59 1	61 6½	61 6½	61 4	59 1	57 9½	56 11	60 2	59 2	58 5½	57 7	59 7½
1909	51 4	56 5	55 3	56 1	56 4	57 0	56 8	58 0	61 0	61 1½	60 7½	61 4	58 1½
1910	64 0½	64 3½	66 10½	67 6½	66 2½	65 4	64 4½	65 6½	65 2	64 10½	64 6	65 6	65 4½
1911	66 9	66 1	64 10	63 1	62 1	62 0	61 2	62 2	62 1	61 1	61 10	64 0	63 1
1912	67 0	67 0	67 0	69 3	71 9½	72 11	75 9¾	79 1½	82 2½	85 0	85 3½	86 6	75 9½
1913	86 6	86 6	86 3	85 0	83 6½	80 10½	78 1	76 10½	72 6	71 0	68 0	65 3	78 4½
1914	64 6	65 4½	65 6	64 11½	64 2½	64 0	64 0	68 11½	74 6½	71 0	65 4½	69 9½	66 10½
1915	78 9	100 6	103 1	113 6	111 9	114 0	116 3	115 2½	113 8½	121 1½	131 9½	139 6½	113 3
1916	135 0	135 0	133 4	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	129 2½
1917	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1918	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1919	127 6	127 6	127 6	127 6	180 6	184 3	195 4½	204 6	204 6	204 6	204 6	204 6	174 7
1920	224 9	235 0	245 0	275 0	290 0	295 0	295 0	295 0	295 0	295 0	295 0	280 0	284 11½
1921	263 4	228 4	180 0	180 0	180 0	160 0	160 0	157 6	142 0	128 6	121 0	115 6	167 9½
1922	125 0	117 6	115 0	115 0	115 0	115 0	113 1½	104 0	105 0	105 0	106 3	110 0	112 1½

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WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

18, BENNETTS HILL, BIRMINGHAM.

11, OLD HALL STREET, LIVERPOOL.
EXCHANGE BLDGS., PORT TALBOT.
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FOUNDRY MANAGER, open for re-engagement; has had experience in high-class Grey Iron, Malleable and Gunmetal Foundries, Pattern Shop, Buying, Estimating and Sales; has good connection with buyers; Member of Institution of British Foundrymen; also Cast-iron Research; good references from present and previous employers.—Box 376, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

GENTLEMAN (38) desires responsible post; 20 years' experience Engineering and Foundry Trades; capable of General, Commercial or Sales Management. Unique opportunity for gentleman wishing to retire or ease off, leaving management in capable hands. A really progressive proposition wanted by one not afraid of work.—Address, Box 392, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

ENGINEER REPRESENTATIVES required in all districts, on commission basis only, calling on Engineering Works, Foundries and Factories.—Full particulars as to qualifications, district, etc., to Box 281, c/o JUDD'S, 87, Gresham Street, E.C.2.

REPRESENTATIVE (Salary and Commission) required by London firm having exclusive sale high-grade English pig-irons. Applicants must possess genuine live connection in Southern Counties, and able to introduce superior material.—Full particulars on application to Box 404, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

WANTED, Foundry Foreman with extensive experience in Machine Moulding; must be thoroughly up-to-date and have sound references as to organising ability and piece-rate fixing; also fully experienced in Cupola Practice and Mixture of Metals.—Reply, giving all necessary particulars, to Box 394, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

AGENCIES.

BEECROFT & PARTNERS, LTD., Metallurgical Works, St. Peter's Close, Sheffield, invite applications from Agents calling on Iron and Non-Ferrous Metal Founders to represent them in London, South Wales, Belfast and Birmingham areas, respectively, for their widely used Corbeerite Products.

CZECHO-SLOVAKIAN REPUBLIC. — Trading Firm, with domicile in Prague, want to take up the Agency of only large houses for Pig-iron, Tin, Copper and other Metals. Partner is coming to London early in April.—Letters to OSKAR MAUTNER & Co., Královská tr. 79, Praha-Karlin.

ENGINEER, Smart Traveller, residing Manchester, is open to Sell Pig-iron in Lancashire, Cheshire and Sheffield for British Maker of Foundry Brands.—Address, Box 402, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

PROPERTY.

IRON AND BRASS FOUNDRY FOR SALE.—Going concern, with live connection; situated West London; fully equipped with Cupola, Pit Furnaces, Moulding Machines, etc. Floor space over 4,000 ft. Price £1,500.—Apply Box 398, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

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5 ft. SAND MILL, as new.

Two VERTICAL BOILERS, by Ruston, 13 ft. 9 in. high x 6 ft. 3 in. dia., 120 lbs. w.p.

Ditto, by Robey, 8 ft. x 3 ft., 80 lbs. w.p.

100 h.p. VERTICAL HIGH-SPEED ENCLOSED STEAM ENGINE, by Belliss, 140 lbs. w.p.

31 h.p. CROSSLEY GAS ENGINE, latest type.

15 h.p. ELECTRIC MOTOR, 220 volts D.C., with starter.

Weir Type BOILER FEED PUMP, 1,500 gallons per hour.

Hind & Lund DRYING and MIXING MACHINE, heavy geared type; new condition.

HARRY H. GARDAM & CO., LTD., STAINES.

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WANTED, Tilghman Compressor, suitable for sand-blasting, or would purchase complete plant.—Box 386, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

WANTED, one No. 9 Ajax Turnover Moulding Machine; also one Core Wire-Straightening Machine.—Box 400, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

Three Lancashire Boilers, 30 ft. x 8 ft.; reinsure 160 lbs. working pressure; new 1916. Two nearly new Steel Lancashire Boilers, 30 ft. x 9 ft.; reinsurable at 100 lbs. working steam pressure; complete with steam and furnace fittings, etc. Five Lancashire Boilers, 30 ft. x 7 ft. 6 in.; now insured at 150 lbs. pressure. One Lancashire Boiler, 30 ft. x 8 ft. 6 in.; for 100 lbs. pressure. Cochran Vertical Boiler, 16 ft. 3 in. x 7 ft. 6 in. diameter; reinsure 80 lbs. pressure. Two Marine Boilers, 10 ft. 4 in. x 12 ft. 2 in. diameter; reinsure 150 lbs. pressure. "Galloway" Boiler, 24 ft. x 6 ft. 8 in. diameter; reinsure 100 lbs. pressure. Four Circular Tanks, 13 ft. x 6 ft. diameter x ½ in. plates; fitted with internal stirring gear.

Catalogue of Stock Machinery, 6,000 Lots, Free on application. Inspection invited.

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PATENTS.

INVENTORS Advice, Handbook and Consultations Free. KING'S PATENT AGENCY, LIMITED, Director, B. T. King, Regd. Patent Agent, 146a, Queen Victoria Street, London; 36 years' references.

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PLUMBAGO.—One ton only; cheap for quick sale. GOVERNMENT STORES, Lytham, Lancs.

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Enquiries solicited for pattern making. Good deliveries.

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THWAITES' Cupola, 30 in. diameter, with charging platform, roof, ½-ton electric hoist, electrically-driven Roots' Blower, complete with Motors, 440/480 volts D.C. Price, including motors and control gear,

£200, f.o.r. London.

Without electrical equipment **£150.**

2-TON MORRIS Hand Travelling Crane, with about 60 feet of runway girders, span 40 feet (will alter if required), **£50,** f.o.r. Good as new.

BELT-DRIVEN AIR COMPRESSORS.

INGERSOLL, NEW and UNUSED, 464 ft. to 100 lbs., **£275.**
ROBEY, 2-stage, vertical, 1915, 400 ft. to 100 lbs., **£260.**
CHICAGO, horizontal, 8 in. x 8 in., 80 ft. to 100 lbs., **£55.**
REAVELL, vertical, practically new, 50 ft. to 100 lbs., **£42.**
REAVELL, horizontal, 2-cyl. opposed, 13 ft. to 100 lbs., **£20.**
All above good condition, and water-jacketed cylinders.
100-lb. RECEIVERS, 15 in. x 5 in., vertical, **£50**; 23 ft. x 3 ft., horizontal, **£40**; 5 x 2½, **£10.**

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